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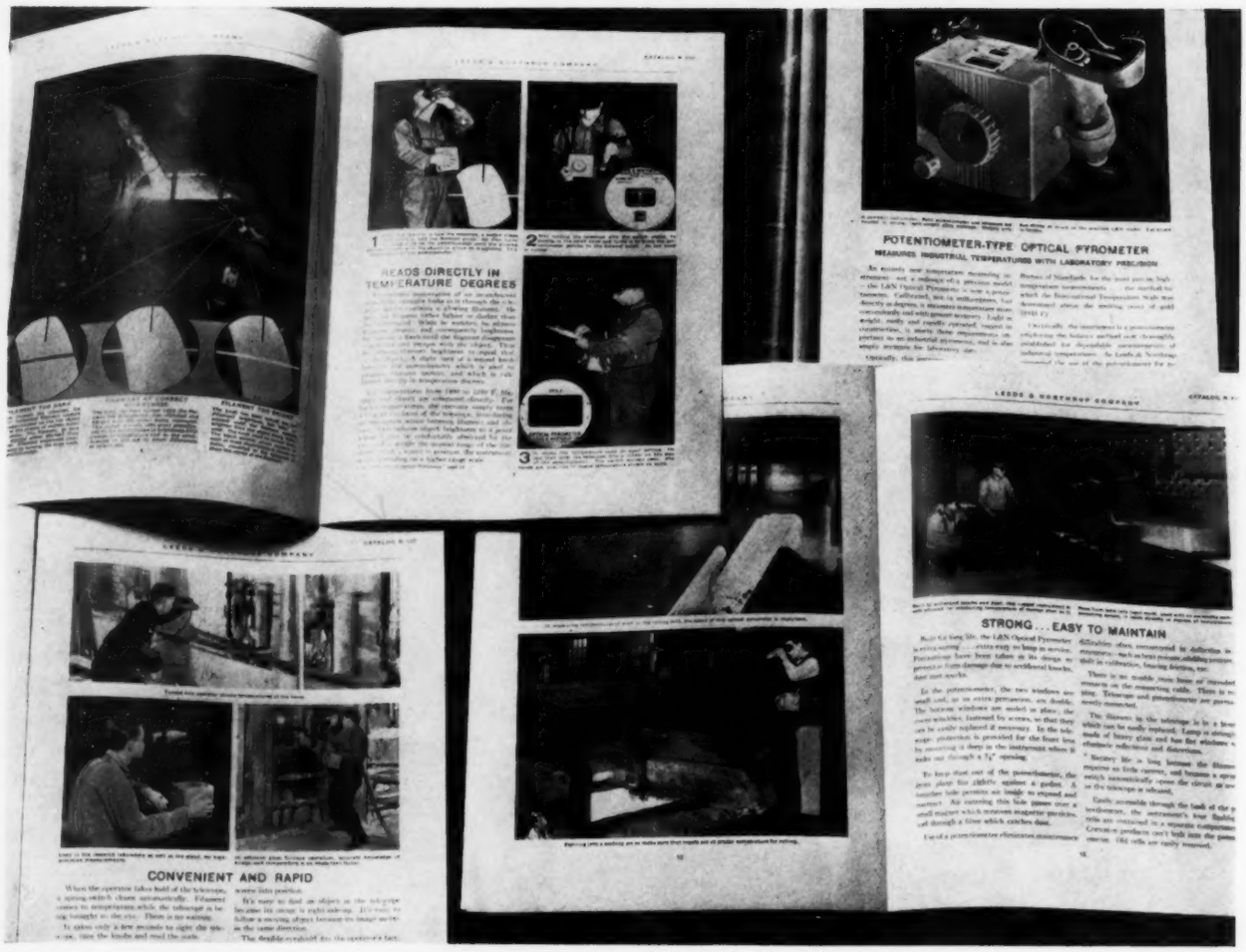
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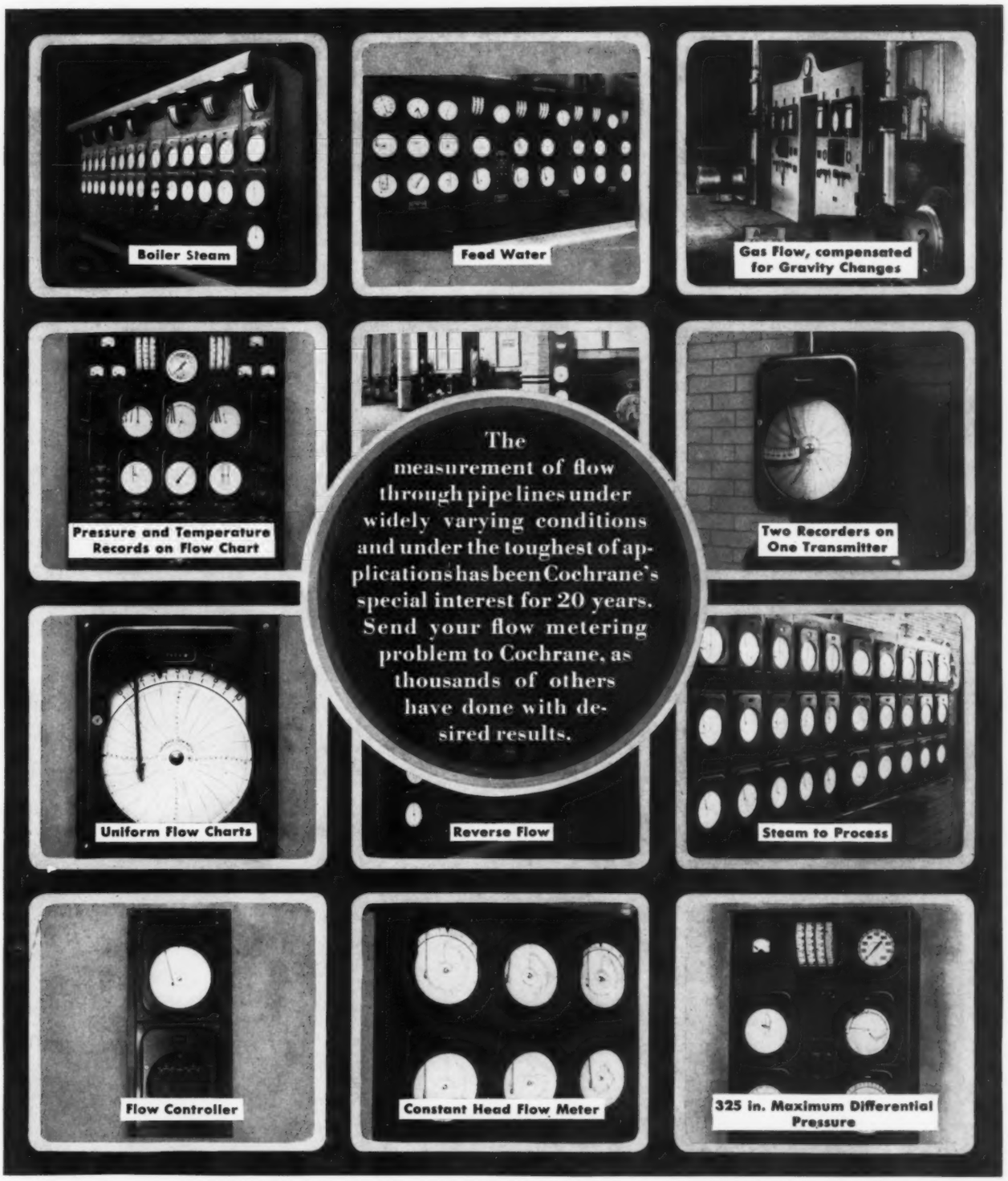
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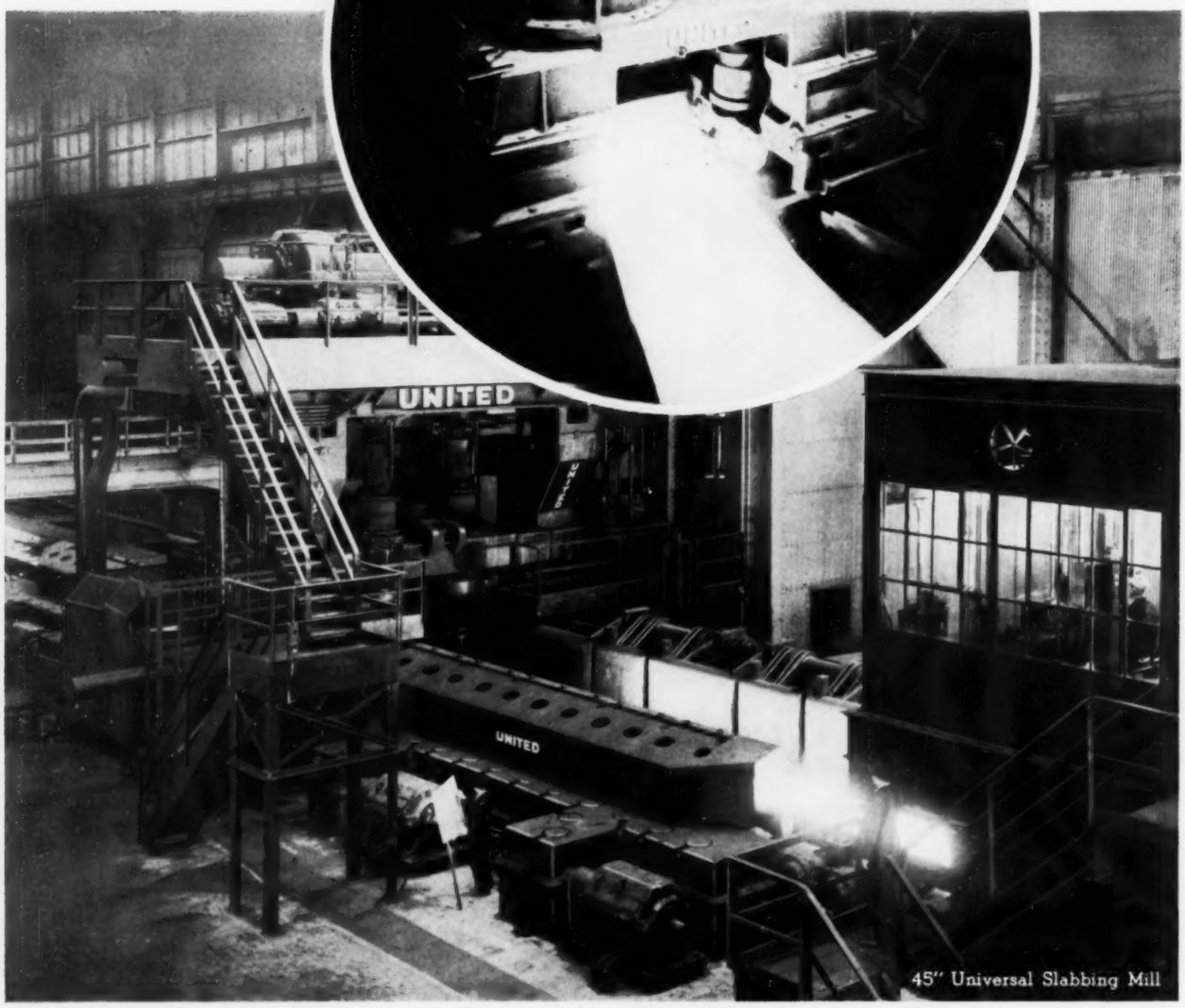

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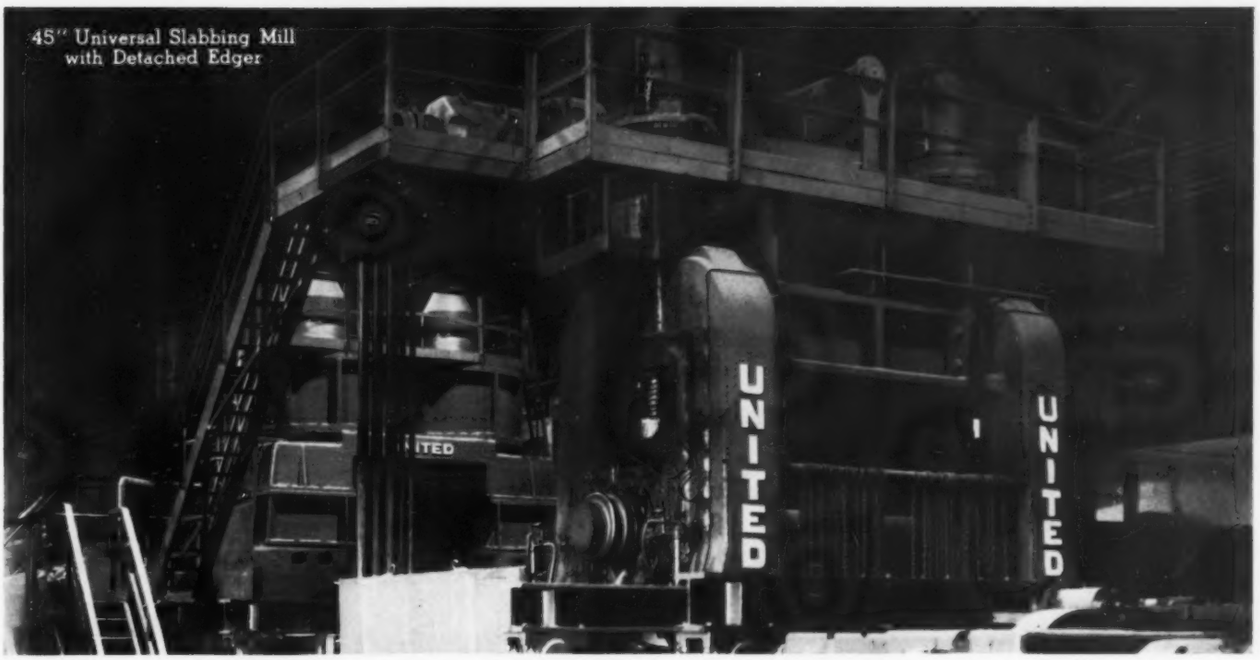
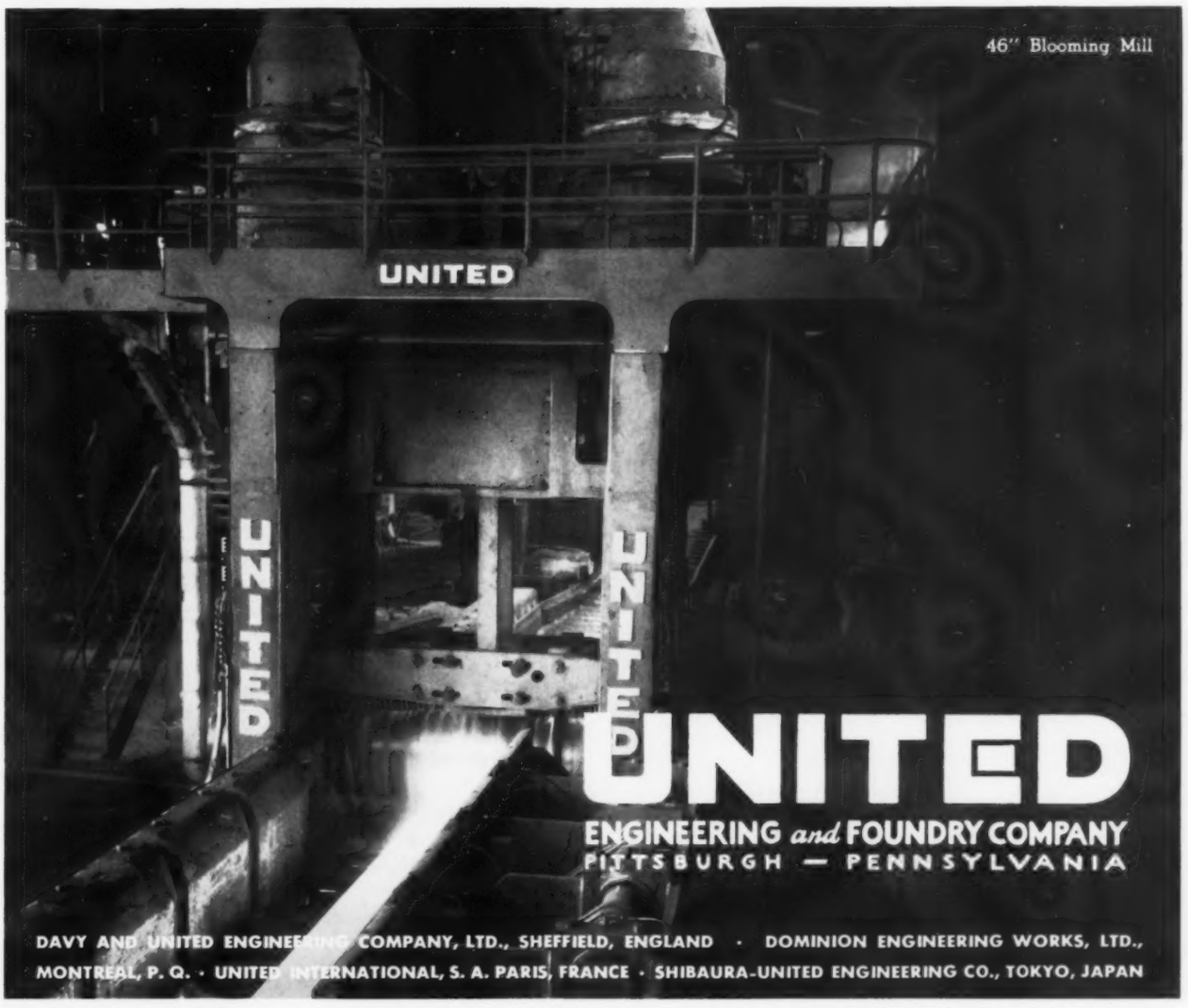


Installations ★ ★ ★ ★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HOT ROLLING of BLOOMS and SLABS

By M. P. SIEGER

UNITED ENGINEERING & FOUNDRY CO.

PITTSBURGH, PENNA.

Presented before E.S.W.P., Pittsburgh, Penna., October 20, 1939.

▲ AS a preliminary step towards forming steel into the various sections which its many uses require, the heavy ingots are first roughly reduced, in mills specially designed for the purpose, to much lighter but still very simple sections, as the round, the square, and the rectangle.

When the ingots have been reduced to the size and shape required, they are known as either blooms or slabs depending on their cross section. These are produced for further rolling into a semi-finished product by billet, sheet bar, and skelp mills; and into a finished product by plate, rail, structural, and strip mills.

If the output of the mill is mainly blooms, the mill is called a blooming mill, and if slabs a slabbing mill. Several types of these mills are in operation today; consisting of the continuous mill for the production of blooms only; the three-high mill, also for bloom rolling only; the two-high reversing mill with manipulators for both bloom and slab rolling; and the two-high reversing universal mill, which is used primarily for slab rolling.

Rolling mills are somewhat like houses; thus, while they are alike as to gross features, they differ greatly as to the scale of construction. Just as the architect will strive to impart individuality to a building, so the rolling mill engineers will endeavor to introduce new ideas looking to greater improvement in construction; and just as it is desirable to adapt a building to its location and surroundings so is it found necessary to alter the details of mill construction to suit conditions. The result of all these influences has been to produce a wide variety of mills, each having certain advantages to meet the individual requirement.

It is impossible to describe in detail all the various types and arrangements during the time allotted. I have, therefore, taken the liberty of confining this paper to the design of two of the most recent installations. They are the installation made at the Edgar Thomson plant of the Carnegie-Illinois Steel Corporation and the one at the Middletown plant of the American Rolling Mill Company.

M. P. SIEGER

Carnegie-Illinois Steel Corporation

Edgar Thomson Works

UNIVERSAL SLABBING MILL

This installation combines all the features known to give flexibility of operation in the rolling of ingots into slabs. The mill is of the universal type, *i.e.*, it has both horizontal and vertical rolls, permitting the rolling of both the sides and edges of the slab during a single pass.

Ordinarily, the operation of this type of mill does not include edge rolling on the horizontal rolls thus eliminating the necessity for a manipulator, but as installed at the Edgar Thomson Works, the mill includes manipulators with tilting fingers on both the entry and exit sides of the mill. This gives a maximum flexibility to the operations, permitting edge rolling as desired on either the horizontal or vertical rolls.

Edge rolling on the horizontal rolls has proven somewhat of an advantage for descaling, as this procedure breaks the scale away from the sides of the ingot before these surfaces are rolled.

This mill is designed to roll ingots 21 in. to 33 in. thick, 25 in. to 66 in. wide, and up to 90 in. long; weighing 10,200 to 45,000 lb. The slab sizes range from

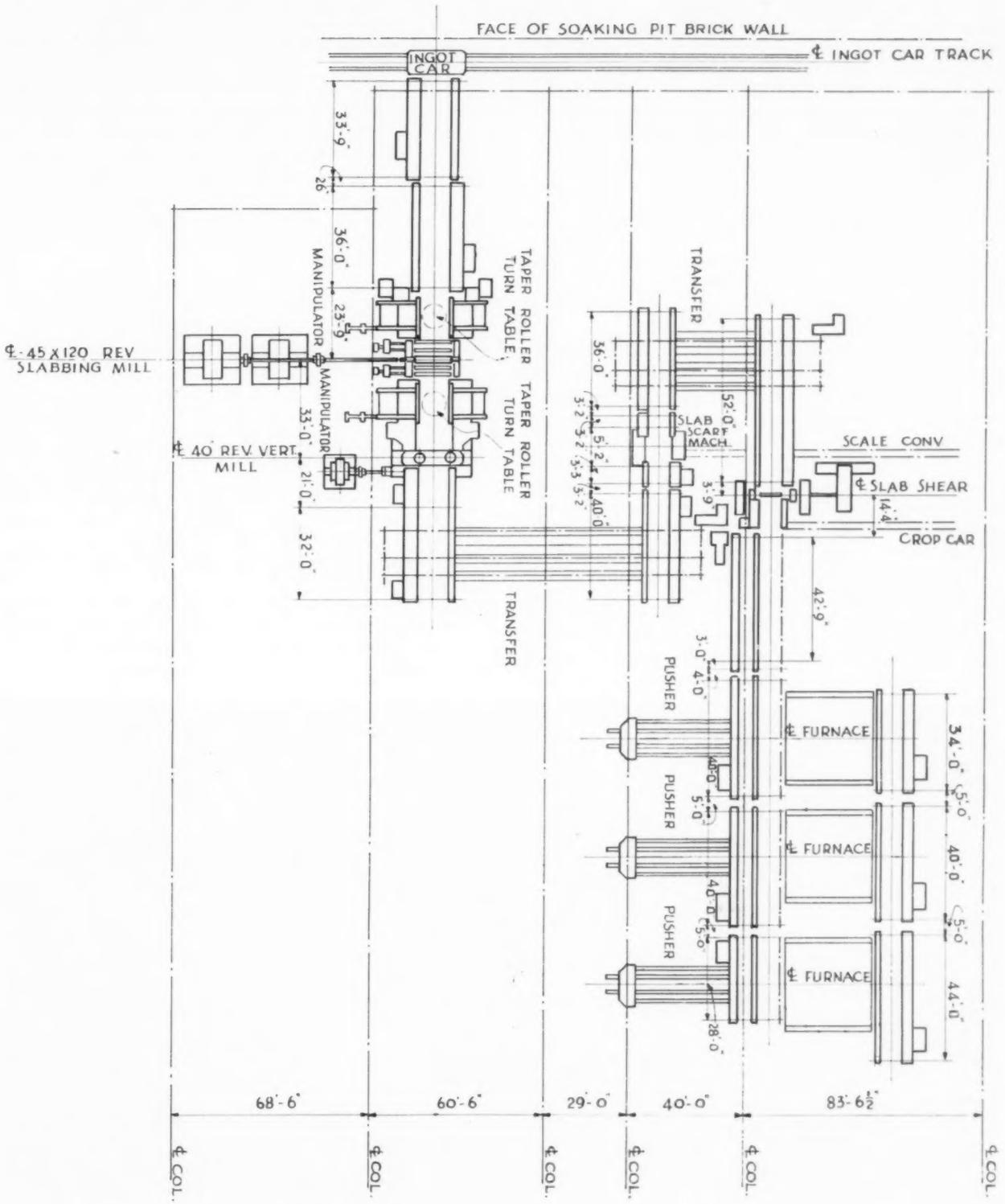


FIGURE 1—General plan of a typical blooming mill installation which is arranged to give maximum production with great flexibility of operation.

2½ in. thick, 18 in. wide, 60 in. long, to 8 in. thick, 60 in. wide, 20 ft. 0 in. long.

A general plan of the entire installation is shown in Figure 6 and consists of the following: ingot buggy, ingot receiving table, ingot turner and scale, mill approach table, front and back reversing mill tables, manipulators, universal roll stand, mill runout table, shear approach table, slab shear and gauge, crop conveyor, shear runout table with slab weighing device, transfer table, transfer, piler tables, and piler.

THE HORIZONTAL ROLL STAND

The horizontal roll stand is designed for a maximum pressure between the rolls of 4,000,000 lb. The rolls have 45 in. diameters by 80 in. long bodies with 28 in. diameter, 34 in. long necks.

Each roll is independently driven by a 5000 hp., 0-40-80 rpm., 700 volts, d-c. reversing motor, making a total of 10,000 hp. input. The operating speed range of the mill is 0-476-952 fpm. The maximum opening between the rolls is 66 in.

The roll neck bearings are of the babbitted with bronze insert type, and are grease lubricated and water cooled. They are 28 in. long, and are subjected to a pressure of 2,560 lb. per square inch of projected area when the full pressure of 4,000,000 lb. is developed.

The housings are cast steel, having a post cross sectional area of 700 square inches. They are designed to accommodate the mounting of two feed rollers on the entry side of mill and one feed roller on the exit side. The housing window and fillings are designed for simultaneous withdrawal of both the top and bottom roll assemblies by a motor operated roll changing rig. The top roll is balanced by a counterweight arrangement, which is located beneath the roll stand with bars extending vertically through the bottom of the housings to the top roll carrier.

On this type of mill where the ingot is edged on the horizontal rolls, the screwdown must have a very high operating speed, as the top roll must be raised an amount equivalent to the width of the ingot. It is also necessary that the unit be operated at a comparatively slow speed to permit accurate positioning of the rolls. With this thought in mind, together with smoothness of operation and reduced control maintenance, a variable voltage control was installed.

The housing screws are 18 in. diameter and have 2¼ in. pitch single buttress threads. They are driven through spur and worm gearing by two 200 hp., d-c., mill type, shunt wound motors, and have a maximum lifting speed of 26 feet per minute at 615 rpm. of the motor. A dial type mechanical roll opening indicator, selsyn motor driven, is located in the operator's pulpit.

The spindles are of the universal type with the bottom spindle spring balanced and the top spindle balanced by a counter-weight arrangement similar in design to the top mill roll balance. A view of the mill is shown in Figure 3.

FIGURE 2—Shown in the center of this view is a turning device, mounted on a scale, that automatically weighs the ingot. Immediately beyond is shown the ingot buggy.

THE VERTICAL ROLL UNIT

The vertical rolls are located on the exit side of the mill and are driven through spur and bevel gearing by a 3,000 hp., 0-60-180 rpm., 700 volts, d-c., reversing motor. The operating speed range of the vertical rolls is 0-276-828 fpm., making possible the synchronization of the roll speed with the slab entering speed to the horizontal rolls over the entire range of pass reduction.

Prior to the designing of this mill, the universal mill had considerable disadvantages. These were the inaccessibility of parts due to the type of construction, it being necessary to dismantle a portion of the vertical roll drive to permit changing of the vertical rolls. This design also required an excessive horizontal roll body length to obtain the required maximum opening between the vertical rolls. These disadvantages are overcome by the design used in the construction of the Edgar Thomson mill, as the vertical roll unit is constructed as an independent unit and connected by proper means to the horizontal roll stand. The construction eliminates the necessity for excessive horizontal roll body length, and also permits roll changing without dismantling any part of the vertical roll drive. However, it is necessary to remove the top guide bar. This bar is handled by a mill crane which utilizes a C-hook designed for changing both the vertical rolls and the guide bar.

The unit is designed for a maximum pressure between the rolls of 1,500,000 lb. The rolls have 36 in. diameter, 80 in. long, bodies with 22 in. diameter, 32 in. long necks. I might add at this point that both roll ends are duplicates, and it is therefore possible to turn the roll end for end, thus giving double life. Each roll is adjusted horizontally by a 75 hp., 500 rpm., mill type motor. The maximum opening between 36 in. diameter rolls is 82 in., the minimum 18 in. Each roll is driven through a bevel and single helical gear drive by a common splined shaft from the main reduction gear drive. The rolls are driven through a loose coupling box of the four pod type, which can be raised free of the end of the roll and latched into position for roll changing. A view of the vertical roll unit is shown in Figure 4.

AUXILIARY EQUIPMENT

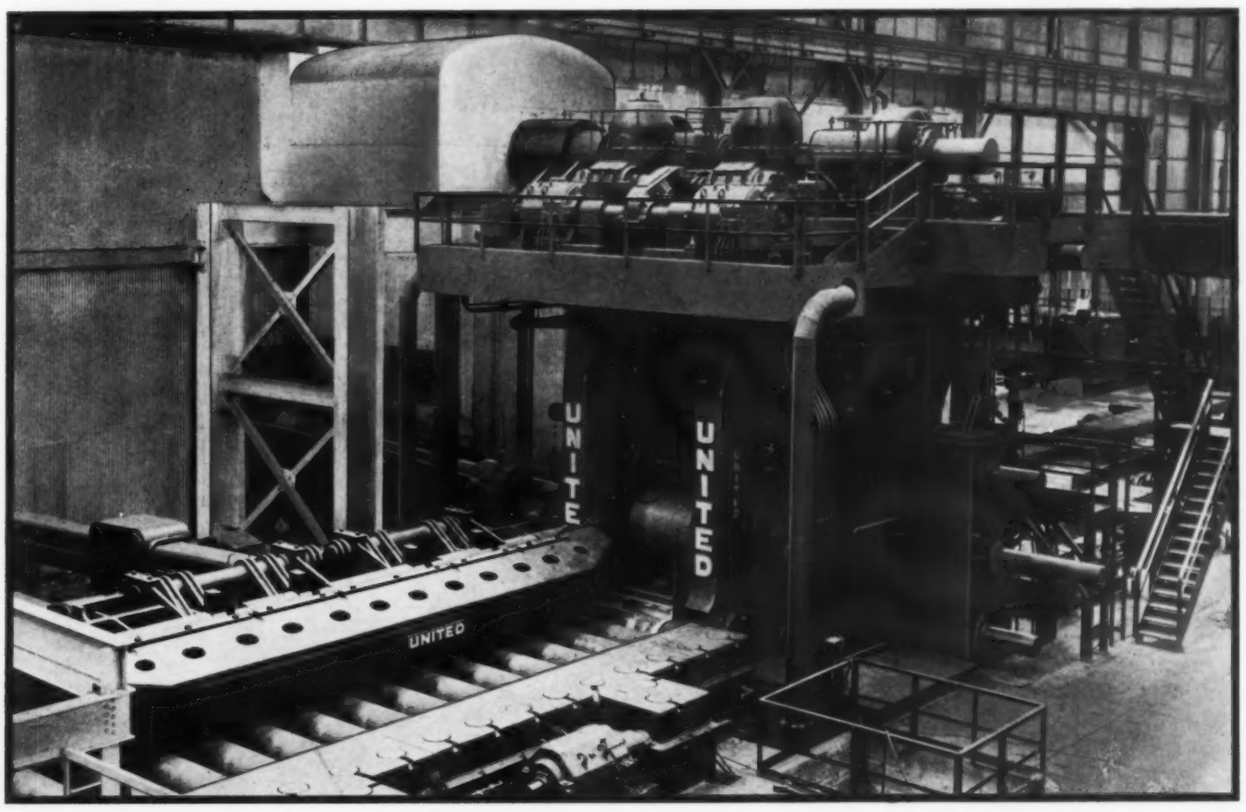
Many features are incorporated in the design of the auxiliary equipment which I believe worthy of mention.

Ingots are transported from the soaking pits to the ingot receiving table by a buggy, which operates at speeds up to 500 fpm. The buggy is driven by two 50 hp., railway type, motors, axle mounted. The ingot is deposited on the table by a cam arrangement located at the entry end of the table, which tilts the ingot pot as the car approaches the table.

Between the ingot receiving table and the mill approach table, a turning device is installed to permit turning the ingot end for end when desired. This device is mounted on a scale that is both indicating and recording, and automatically weighs the ingot as it passes this point. (Figure 2.)

I might elaborate at this point and explain this

FIGURE 3—The horizontal roll stand in this view is designed for a maximum pressure between the rolls of 4,000,000 lb.



feature. As the ingot is placed into the ingot buggy by crane in the same position as cast, the top or piped end is on top and when deposited on the table, this end is leading into the mill. If rolled in this position, the front end of the slab would contain metal from the piped end of the ingot, requiring considerable guess work on the part of the shearman to determine what amount of front crop is to be removed. If an excessive amount of front crop is removed, this may result in an off length slab. When the ingot is turned with butt end leading, the shearman can determine definitely the length of the front crop, and obtain a maximum of good metal in the lengths cut.

HOT SLAB SHEAR

Mechanically, the hot slab shear is interesting in that it combines the advantages of both the upcut and downcut types of shears. The action is such as to permit the lowering of the top knife until it rests on the slab to be sheared, thus providing a perfect holddown, or gag. Then the bottom knife raises to complete the shearing operation, lifting the slab only to its own thickness. This shear action eliminates the depressing table, which is a high upkeep item, and also minimizes slab distortion. The shear is driven through a double reduction drive by two 350 hp., mill type, shunt wound motors, and is operated by starting and stopping the motors for each cut, eliminating the necessity for a clutch. The shear has a maximum opening between the knives of 13½ in., and is designed to shear an 8 in. thick, 60 in. wide, hot slab.

A moving table is located on the delivery side of the shear, which moves back to permit the front crop to drop through to the crop conveyor located below the table. This table is also equipped with adjustable side guards for lining up the last piece, so that a square cut is obtained. The rear crop is pushed into the same opening in the table by a crop pusher ahead of the shear; this eliminates a serious heat condition that exists on shears without a pusher, and should prevent cracking of knifeheads and shear knives from excessive heat. A view of the shear is shown in Figure 5.

THE PILERS

The pilers are divided into two sets of two pilers each. Each piler consists of a screw operated, motor driven, raising and lowering piling section, with a motor operated piling pusher. A second motor operated pusher is provided to remove the pile from the movable section, placing it on a stationary set of skids in position for crane removal.

All tables are equipped with solid forged steel rollers which are roller bearing mounted. The rollers are motor driven through double reduction spur and bevel gear lineshaft drives.

The operating speeds of the various tables are as follows:

Ingot receiving table—200 fpm.

FIGURE 4—In this installation the vertical roll unit is constructed as an independent unit. The construction eliminates the necessity for excessive horizontal roll body length.

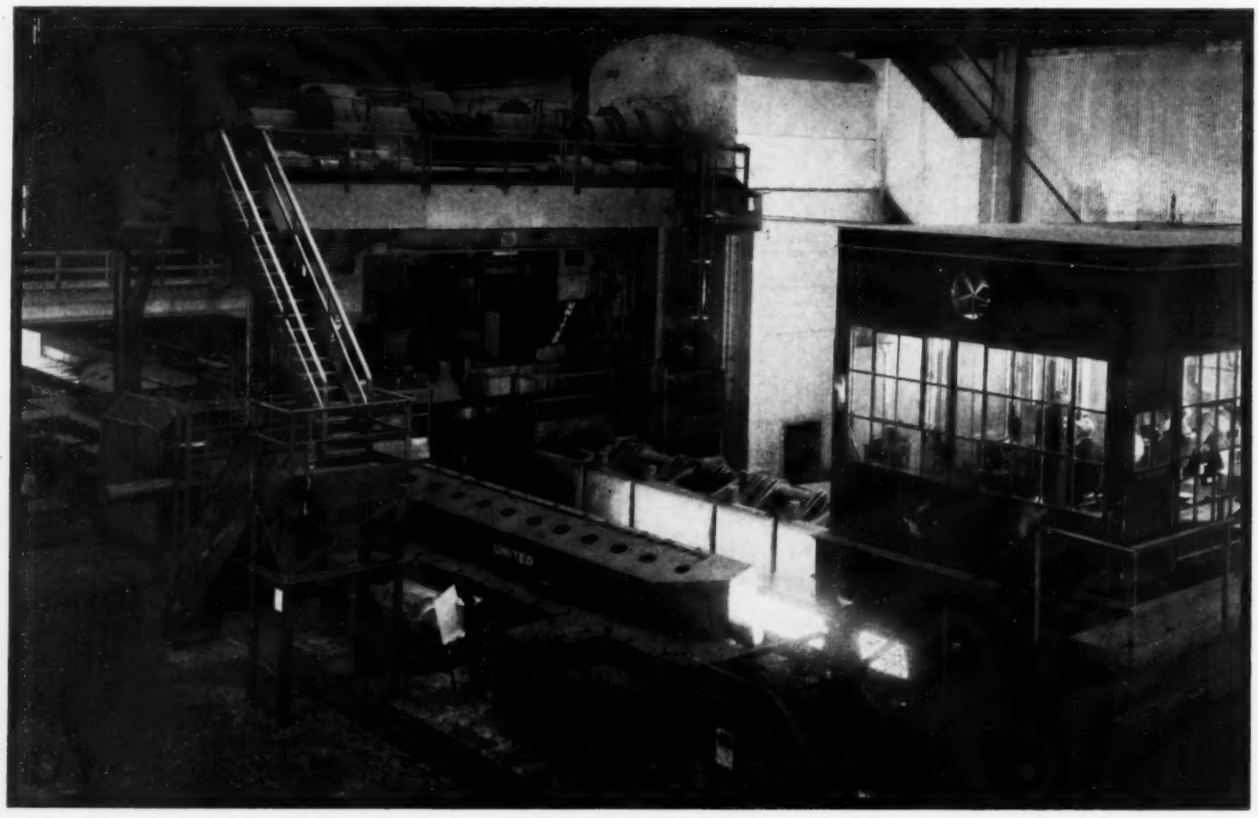
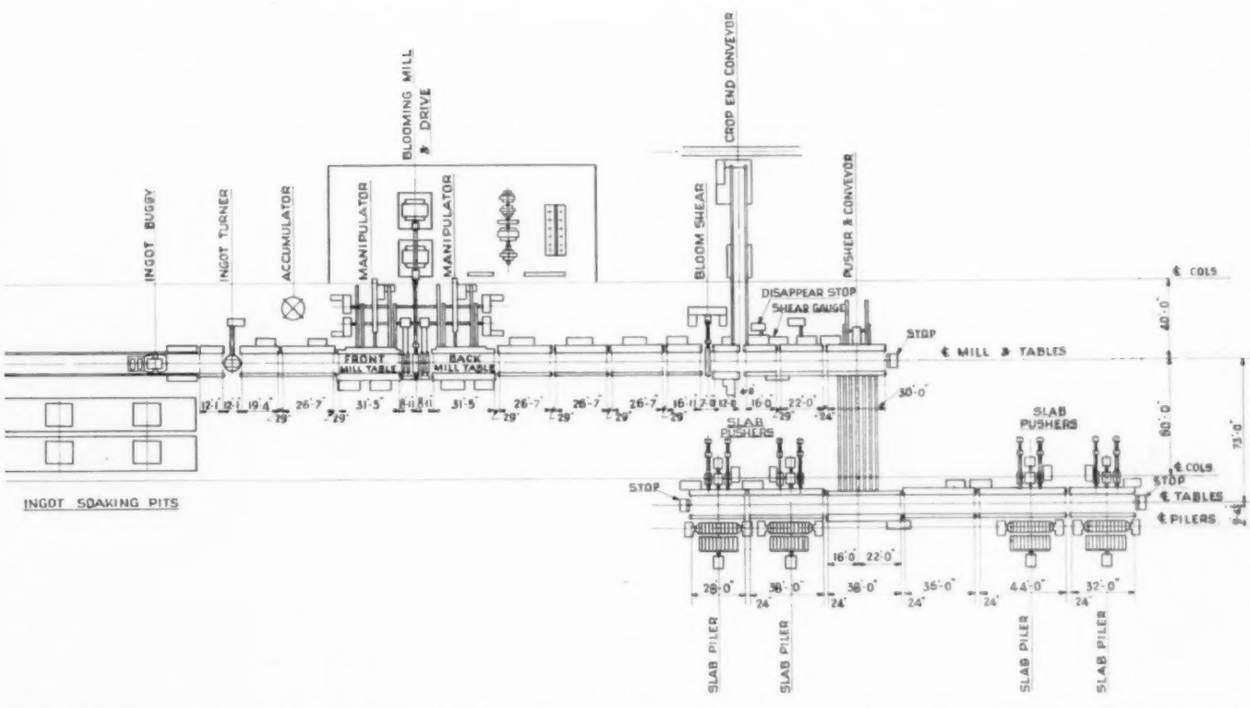


FIGURE 5—The hot slab shear shown here combines the advantages of both the upcut and downcut types of shears.

(Above)

FIGURE 6—General plan arrangement of a slabbing mill designed to supply slabs for an 80 inch continuous hot strip mill.

(Below)



Mill approach table (first section)—300 fpm.
Mill approach table (second section)—400 fpm.
Front and back mill tables and feed rollers—415 fpm.
Mill runout table—400 fpm.
All shear, transfer, and piler tables—300 fpm.

American Rolling Mill Company

Middletown Works

REVERSING SLABBING MILL

To appreciate the features included in the design of this mill, it is necessary that we have a knowledge of present day hot and cold strip mill operations. Let us, therefore, digress for a moment and consider these operations, for after all the design of the slabbing mill must be based on the requirements of all subsequent operations to obtain a maximum result from all of the units used.

The sequence of operations used in the production of cold reduced strip is usually as follows:

Slabs are produced on the blooming, or slabbing mill and usually conditioned for the hot strip mill in the slab yard. They are then reheated and rolled into strip, and coiled by the hot strip mill coiler. The coils are then pickled, cold rolled, annealed, temper passed, and sheared to length. These operations may vary to suit local conditions, but they are the practice of a majority of plants.

Large coils are required to economically operate a high speed, multiple stand, tandem cold mill. However, the size of coil is controlled by the size of slab available.

With present day casting methods, 66 in. seems to be the practical limit for ingot width. This limits the width of slab to approximately 60 in., which is perfectly satisfactory for strip up to this width; but requires a broadsiding operation by the hot strip mill to produce strip of greater width, which is produced in great quantity for the automotive trade.

However, this broadsiding operation limits the length of slab to the width of the broadsiding mill stand. The largest mill stand used today for this purpose is 130 in. wide, and it is apparent that the slab cannot be over 120 in. long.

As all units of a hot strip mill are designed to handle slabs up to 18 ft. 0 in. long, it is apparent that it would be a decided advantage if it were possible to produce slabs of greater width than 60 in. in full 18 ft. length, and making possible the production of full weight coils over the entire range of strip widths. This reduces to a minimum welding together of coils for economical cold mill operations.

The Middletown slabbing mill is designed to broadside a 63 in. maximum wide ingot to any width desired. After broadsiding, the ingot is turned for lengthwise rolling into a finished slab.

Thus slabs of full length covering the entire range of strip widths can be supplied to the hot strip mill, eliminating the broadsiding and squeezing operation by the strip mill.

There are other advantages to this installation which I believe worthy of mention, as they simplify the equip-

FIGURE 7—This horizontal roll stand installation is designed for a maximum pressure between the rolls of 3,000,000 lb.

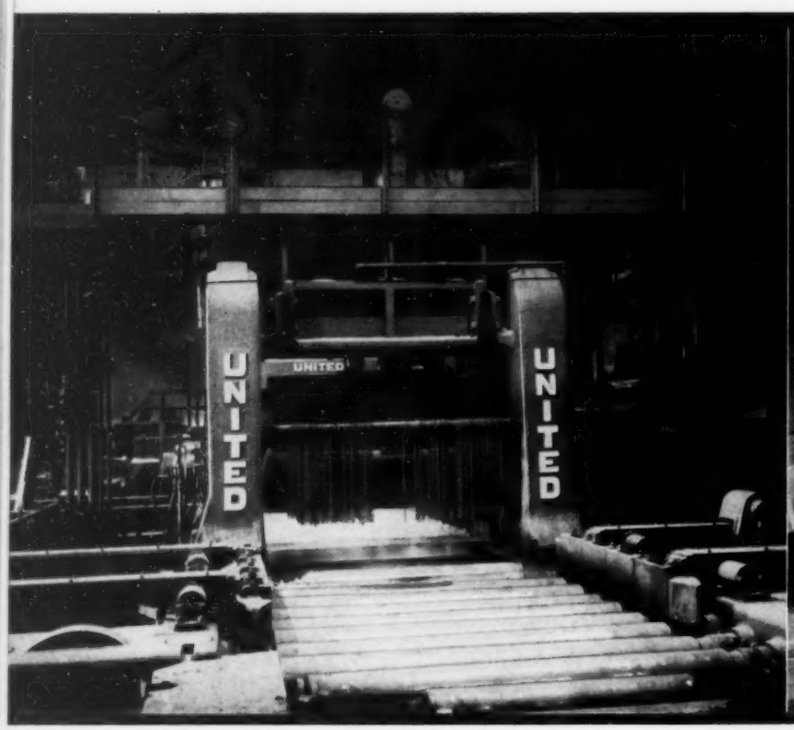


FIGURE 8—View showing the location of the vertical roll stand with respect to the horizontal roll stand.

ment and control, and reduce the initial investment to a minimum. As all edge rolling of both the ingots and slabs is performed by the vertical roll stand, the lift of the top horizontal roll is reduced to a minimum, the amount of lift required being equivalent to the maximum thickness of the ingot. This reduces the necessity of the high speed operating screwdown, as is required for mills that require lifts of the top roll equivalent to the maximum width of slab. This results in a reduction of the cost of the electrical equipment and controls.

A general plan view of the entire installation is shown in Figure 1, and consists of the following: ingot buggy, mill approach table, front and back mill tables with turn tables and centering side guards, two-high reversing roll stand, a vertical roll stand, mill runout table, slab transfer, scarfing machine approach table, slab scarfing machine, runout table with turnover device, transfer, shear approach table, hot slab shear and gauge, shear runout table, and strip mill furnace approach table.

THE HORIZONTAL ROLL STAND

The mill is designed to supply the 80 in. continuous hot strip mill with slabs 4 in. to 6½ in. thick, 24 in. to 76 in. wide, and 16 ft. long, which are rolled from ingots 19 in. to 20 in. thick, to 63 in. wide, and 65 in. to 70 in. long, weighing 19,000 to 25,000 lb.

The horizontal roll stand, Figure 7, is designed for a maximum pressure between the rolls of 3,000,000 lb. The rolls have 45 in. diameter, 120 in. long bodies with 27 in. diameter, 33½ in. long necks. The roll neck bearings are of the fabric type, water lubricated and cooled. They are 27 in. long, and are subjected to a pressure of 2620 lb. per square inch of projected area when the full pressure of 3,000,000 lb. is developed. Each of the horizontal rolls is independently driven by a 5000 hp., 0-40-80 rpm., 700 volts, d-c., reversing motor, making total input 10,000 hp. The operating speed of the mill is 0-476-952 fpm. The driving arrangement is quite similar to that shown in Figure 2.

The housings are cast steel and have a post area of 600 sq. in. The housing window and fillings are designed for simultaneous withdrawal of both the top and bottom roll assemblies by a motor operated rig. The top roll is balanced by a hydraulic cylinder, mounted overhead in the housing top separator.

The screwdown is driven through spur and worm gearing by two 100 hp., mill type, compound wound motors, and with 14 in. diameter, 2 in. pitch single buttress thread screws. The screws have a lifting speed of 3 ft. 4 in. per minute when the motor is operating at 500 rpm. Mechanical dial indicators, selsyn motor driven, are included, indicating the opening between the rolls in $\frac{1}{64}$ of one inch.

The vertical roll stand is located on the exit side of the mill, about 30 ft. from the horizontal roll stand. (Figure 8). The rolls have bodies 40 in. diameter, 24 in. long, and 20 in. diameter necks. They are driven through spur and bevel gearing by a 2000 hp., 0-100-200 rpm., 700 volts, d-c., reversing motor. The operating speed range of the rolls is 0-304-608 fpm. It will be noted that the speed range of the vertical rolls is considerably less than that for the Edgar Thomson mill. This is due to the separation of the rolling units, as it is not necessary to synchronize the edger and horizontal rolls except on the last few passes, which are usually light reductions.

The rolls are adjusted horizontally by two 75 hp., mill type motors. The maximum opening between the 40 in. diameter rolls is 76 in., and the minimum 20 in. A view of this edger installation is shown in Figure 9.

The slab shear is similar to that installed at the Edgar Thomson Works and described previously in this paper.

FIGURE 9—A view of the edger installation at the Middletown plant.

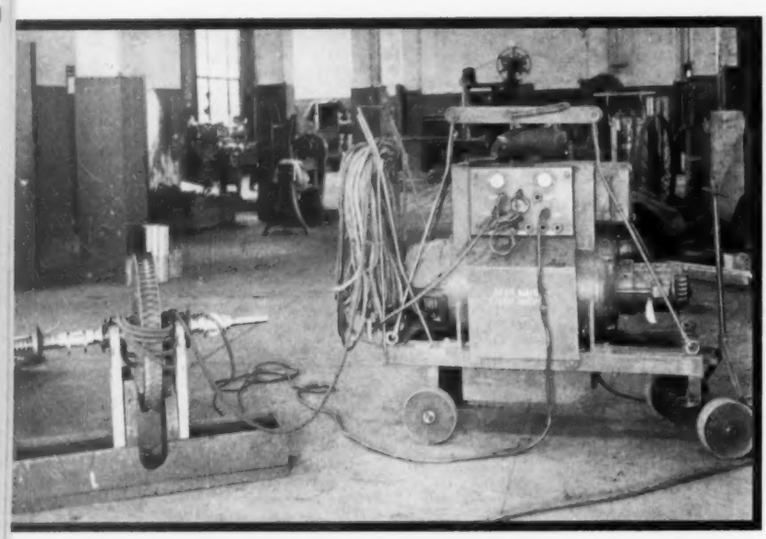


FIGURE 1—View showing method of magnetizing a machine part to be subjected to a magnaflux test.

MAINTENANCE A

By W. F. OBERHUBER

Superintendent of Maintenance

PHILADELPHIA ELECTRIC COMPANY

PHILADELPHIA, PENNA.

▲ IN any discussion of maintenance there are two factors to be considered—the human and mechanical. By human, I mean that which the individuals contribute as an organization. The training which is so necessary for the proper functions of each individual, the work of a well planned inspection group, or the ability the individual can contribute either physically or mentally to the operative work of the entire unit and its higher manifestations must take on an inventive form and must be considered a creative element in the proper functions of equipment. The human efficiency depends, to a large extent, upon knowledge and experience, both of which are essential. But it is this human element which is more difficult to handle since it is effective by numerous sensations. The mental attitude of the human is effected by both external and internal conditions, but the machine, not being effected by the mentality, and not being complicated in its functions by the element of will, is obviously easier to handle. But it is this easier thing which we have to handle which gives us humans the most trouble. With the proper control of both of these, we are able to approach to a solution which one might consider one hundred per cent.

ORGANIZATION

This paper refers to the maintenance of electrical and mechanical power house equipment. Our organization is arranged to utilize the maintenance personnel at not just one power house but all, and the men are transferred from one to the other through the medium of a work dispatcher. Each station is manned with a complement of men who are assigned to the individual power house, together with a floating crew which takes care of extraordinary maintenance and who are dispatched to different locations, dependent on the help requirement factor. This requirement factor has always been a varying thing. We have solved this by keeping a running check on man hour estimates. All work to be done requires an order and each order is estimated as to the man hour requirements. In this way we determine the number of man hours of work estimated and then we determine the number of weeks in which the estimated hours of work should be fulfilled. For instance, for a job estimated at 40 hours and to be completed in one working week of 40 hours, the divisor would be 40 hours, showing one man required. However, it is impossible to accurately predict the actual time required to complete each job and a divisor has been developed based on experience and is the average of all types of jobs. The divisor now in use is 180 hours which corresponds to a completion requirement of 4½ weeks. As a typical example, if we have a total of 7009 hours ahead of us, we would require 39 men.

Another very important help is the centralization of maintenance so that any improvement effected in one power house may be applied to others and this dissemination of information aids greatly in the essential operation.

Another very important help is the training of men. One must realize that in an organization there are always losses by death, by injury and by retirement. It is therefore necessary that this complement of men be maintained by adding apprentices or other skilled help.

It has been our experience that it is best to take young men graduated from high school, although we have considered boys with a lesser education but we prefer high school graduates. He is given a psychological test and this test is based upon tests from what we consider our best graduated apprentices. If he passes this test satisfactorily and after the personnel department has checked up on his recommendations, he is sent to us for an interview. This interview consists of asking the boy what he is interested in, what he wishes to be skilled in—electrical work, mechanical work, sheet metal work, welding, etc.—a general check-up on personality and his attitude towards life in general. The boy, if satisfactory on all counts, is then employed and he is told that he is on probation for six months. This

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Presented before A. I. & S. E.
Philadelphia Section
April 1, 1939

FIGURE 2—This crack in the blading of a 60,000 kw. turbine was invisible to the eye until the magnaflux test was applied.

gives us a chance to check up on his adaptability and interest in the work. He is then assigned to a regular course of apprentice studies. This training has equipped the boys, in most cases, not just to do, but to have a mind that is creative and analytical as well as practical. Some of these boys have advanced in the organization from skilled mechanics to supervisory positions.

INSPECTIONS

Preventive maintenance inspections are helpful in reducing equipment failures and thus eliminating service interruptions. A system of inspections is set up to locate probable failures and to remove these causes before failure actually occurs. To obtain maximum results the preventive maintenance inspection is systematized two ways:

First, as to the period of inspection. Definite time intervals have been established for various classes of equipment based on hours of operation, number of operations or some other measure of service severity.

Second, as to the report on the inspection. For each class of equipment printed forms are supplied, listing the important items to be inspected. The condition of the equipment and the inspectors recommendations are noted on the forms and filed to form a permanent record.

MECHANICAL HELPS

One of the more recent maintenance helps is the application of magnaflux testing. Its value is unmistakable in the field of preventive maintenance. Briefly, this method consists of: first, magnetizing the piece to be tested by wrapping the cable from a welding machine around it and thus setting up a magnetic field; second, a finely powdered magnetic oxide of iron is then dusted on or sprayed on with kerosene as a vehicle. This method is shown in Figure 1. It shows 4 or 5 turns of a welding machine cable wrapped around a turbine wheel. The wheel is magnetized sufficiently to hold a 60 penny nail unsupported. Figure 2 shows a crack found in the turbine blading of a 60,000 kw. turbine. This fault was invisible to the eye until the magnetic oxide piled up at the crack, clearly indicating the failure.

This test is non-destructive in that it may be applied to finished parts without any detrimental effect. It is fairly rapid and is conclusive. By finding such defects, disastrous failures and costly breakdowns may be averted. The magnaflux method is unlimited in scope for steel testing; it will just as readily detect embrittlement cracks in boiler drums as find a cracked axle in your car.

The counter bore tool shown in Figure 3 consists of 4 tool bits mounted on a tapered shank. It was developed to drill holes in a 1200 lb. steam line so that no chips would get in the line. It was necessary to drill

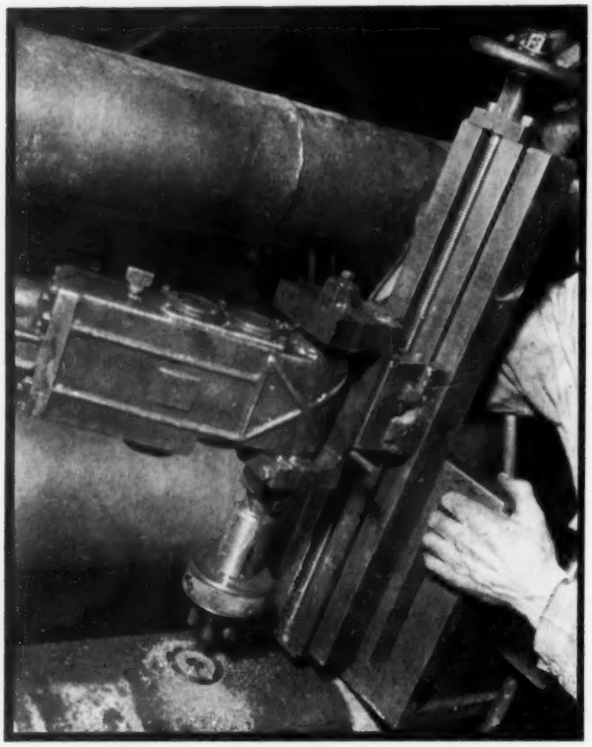
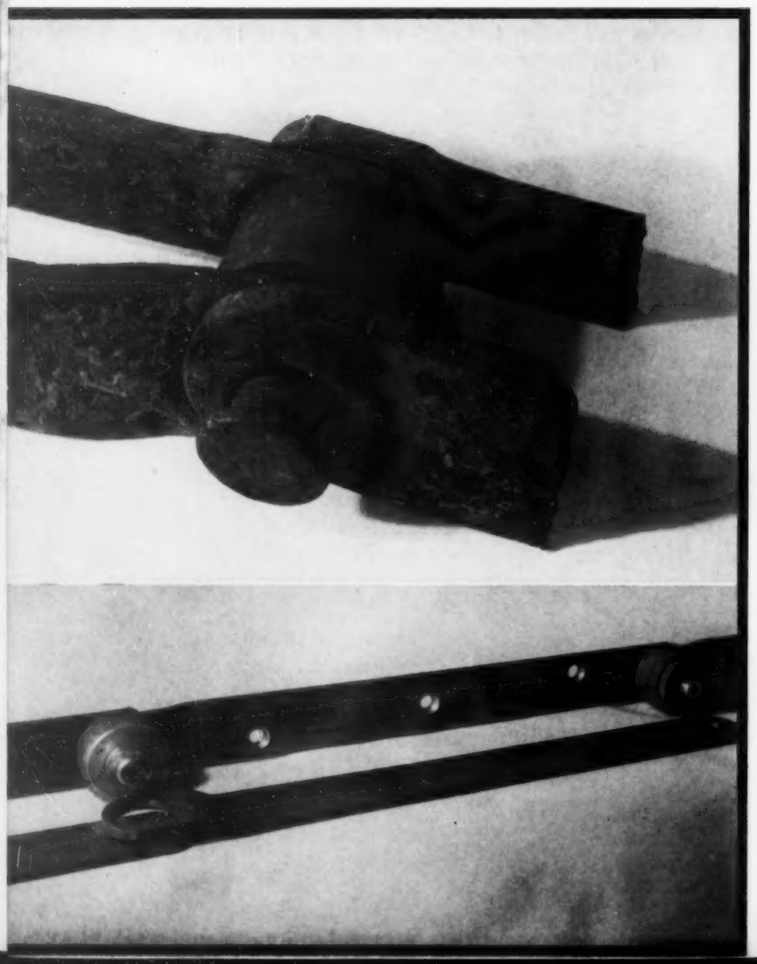


FIGURE 3—This counter bore tool was developed to drill holes in a high pressure steam line without letting chips in the line.

FIGURE 4—View showing construction of link joint from traveling screen, and the manner in which they wear. (Immediately Below).

FIGURE 5—View of new design of link joint, using better grade material, which greatly reduced maintenance. (Bottom).



the holes and at the same time it was impossible to open the welded line to clean out chips. The tool mounted on a corner air machine bores a $2\frac{5}{8}$ in. hole. The pilot is spring loaded so that the depth of the pilot hole does not control the depth of cut. The operation is as follows:

A $\frac{7}{8}$ in. pilot hole was first drilled with a standard $\frac{7}{8}$ in. drill. The pilot hole was not drilled all the way through the pipe wall. The counterbore then cuts through $1\frac{1}{4}$ inches of the $1\frac{5}{16}$ inches of pipe wall. A piece of round stock is welded to the plug and the plug is then broken out and removed. The new lines were then welded to the newly bored hole.

The large volume of water required for condensing purposes in generating stations necessitates their location where water is plentiful rather than at the source of fuel. To prevent fouling of equipment water must be cleaned of a large percentage of dirt and debris before entering the plant. In modern plants such as our Richmond station it requires the screening of some 2,000,000 gallons of water per hour when operating at full load. The screening of this tremendous volume of water is undertaken in a screen house, housing a battery of rotating screen units. Small screens in a suitable frame, are mounted on links which travel around sprockets. The screens are rotated and cleaned as they accumulate the city's waste. Among the many maintenance problems on this equipment were the links upon which are mounted the screens. Figure 4 shows the construction of the link joint and the manner in which they wear. The problem was to get away from the short bearing surfaces of the links. This surface in some chains was $\frac{1}{2}$ inch wide and in others only $\frac{3}{8}$ inch. This problem was solved very neatly as shown in Figure 5. A nickel bearing cast iron wheel rotates on a bronze bushing. The two inside links are welded to the bronze bushing. To a stainless steel pin through the bronze bushings are welded the two outer links. This increases the wearing surfaces the full width of the links, approximately $3\frac{1}{4}$ inches. In addition to better metals and increased bearing surface, lubrication was provided through the stainless steel pin.

Stoker rams and ram boxes of cast iron corrode and wear rapidly due to the chemical action of the coal. Previous practice left no provision for the maintenance of the worn parts. A complete renewal of the rams and boxes was necessary. A non-corrosive material and better wearing surfaces have been provided by the use of stainless steel bushings and liners. This permits easy renewal of worn parts as hereafter described.

The $9\frac{1}{2}$ inches diameter stoker ram (Figure 6) is turned in the lathe to $8\frac{15}{16}$ inches diameter for a distance of $16\frac{1}{2}$ inches from the end. An 18-8 stainless steel plate $\frac{5}{16}$ inches by $16\frac{1}{2}$ inches by $28\frac{3}{4}$ inches is rolled to about 9 inches diameter. This rolled plate is then slipped over the ram and clamped tightly around it. The plate is then welded together along the seam and both ends of the plate to the ram with 18-8 welding rod. The ram is then machined to its original diameter. This leaves only the holes for the connecting rod to be drilled. To make the bushings, a $\frac{3}{16}$ in. x 10 in. x 31 in. 18-8 stainless steel plate is rolled to about $9\frac{1}{2}$ inches diameter. It is slipped over a mandrel, which is accurately machined to the finished inside diameter of the bushing, clamped tightly around it and seam welded.

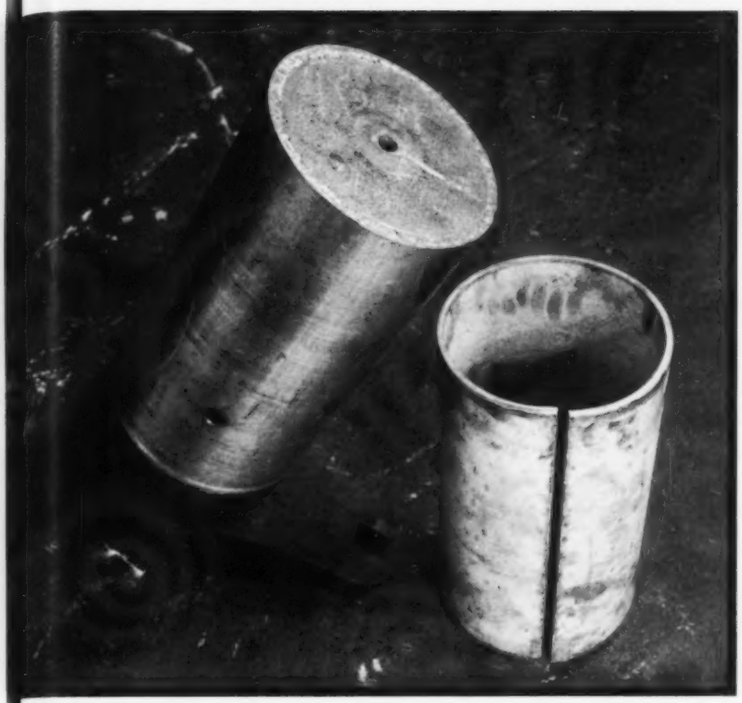


FIGURE 6—Worn stoker rams are reclaimed by turning to a smaller diameter and applying a stainless steel sleeve.

A collar is then clamped near one end of the bushing. The mandrel is ¾ of an inch shorter than the bushing and the part extending over the mandrel is then heated with the acetylene torch and a flange is formed on the bushing by bending the bushing over the collar clamped near the end. The bushing is then machined on the outside diameter before it is removed from the mandrel. It is then only necessary to grind the seam weld on the inside of the bushing with a hand grinder.

The handling of some 1,200,000 tons of coal in a year presents some very interesting handling problems. Since most of the coal is shipped by barge it is unloaded with buckets. The lips of the bucket are rather wide, 6 to 8 inches, extending the width and sides of the bucket. These original bucket lips did not wear well or evenly causing excessive coal leakage during the hoisting of the bucket. Previous practice was to renew this entire lip necessitating considerable machine work and fitting before riveting. The advance of the art of welding both in electric and acetylene now permits us to cut out a narrow section of this wide lip and renew it with a heat treated alloy steel. The alloy steel wears more evenly and lasts much longer.

Higher steam pressures bring new problems. It was desirable to remove a number of tubes in a 1250 lb. boiler to change the circulation. It had to be done in such a manner that the seat would not be injured so that a tight seat could be made when the dummy plugs were rolled in. Figure 7 shows the grooved tube hole. Note the drum thickness: 4¾ inches, and the length of the rolled seat: 2¼ inches. The tube, ⅜ inch wall thickness and 3½ inches diameter, was rolled and flared. This was not an easy job. Figure 8 shows the tube end after removal. The tube was cut off with acetylene outside the drum and the flare cut off inside the drum. The tube end was then heated to approximately 1400 degrees F. and cooled quickly with an air hose. This loosened the tube in the seat. Four acetylene cuts the length of the rolled seat nearly through the wall thickness were then made in the tube. The tube was then

FIGURE 7—Sketch showing grooved tube hole and rolled-in tube on 1250 lb. boiler drum. (Below).

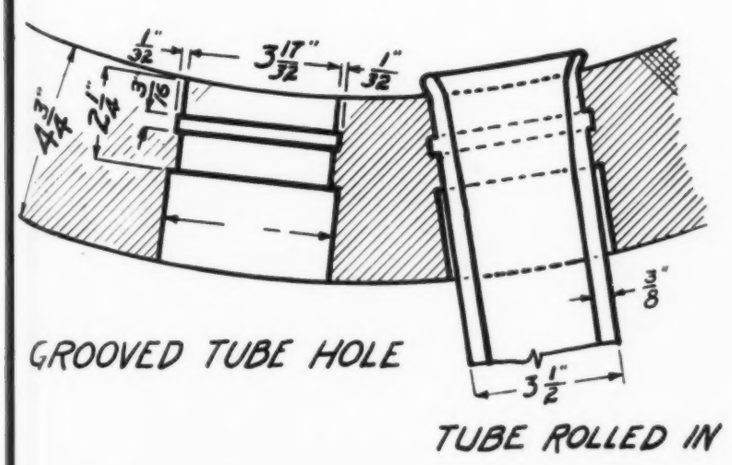


FIGURE 8—View of end of tube after its removal from 1250 lb. boiler drum. (Right).

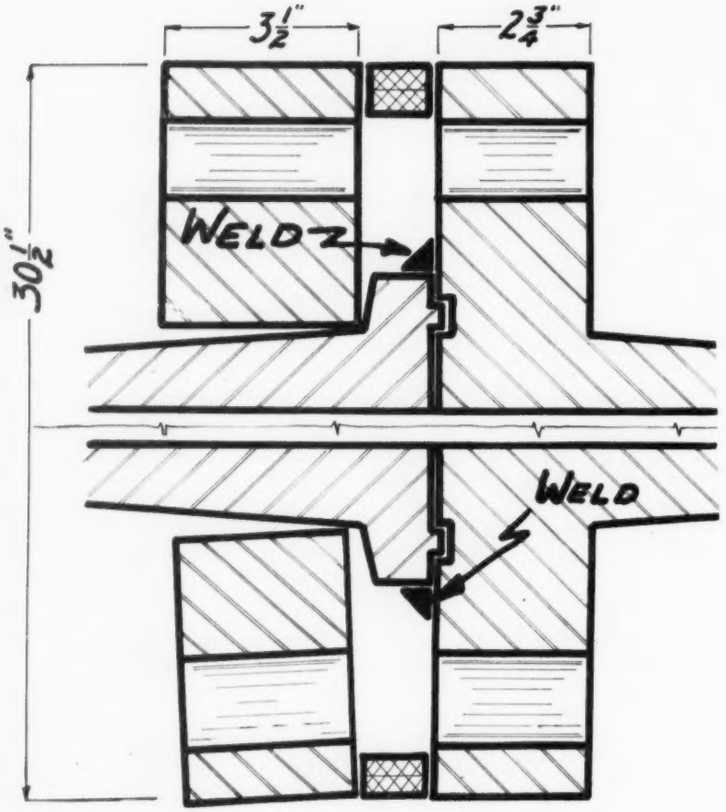


FIGURE 9—Sketch showing method of welding Van Stone type joint to effectively stop leakage. (Above)

hammered in as shown which permitted its easy removal.

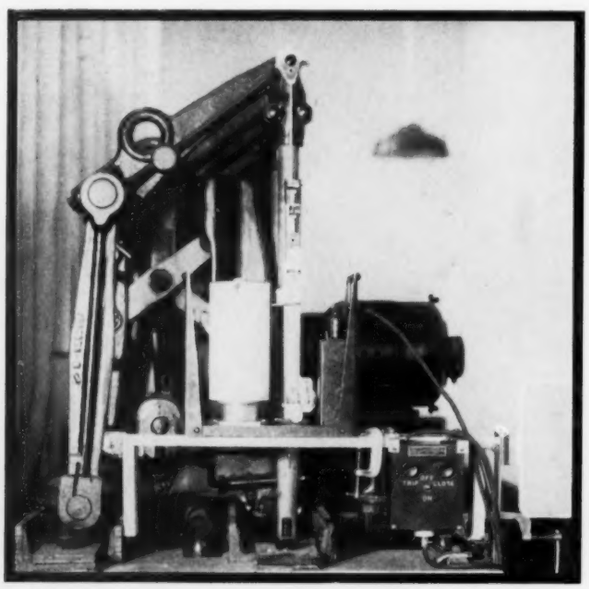
Difficulty in maintaining a tight joint in the high hub Van Stone type flanges as shown in Figure 9 has resulted in seal welding. The Van Stone flange as used in this application made up to a 400 lb. 750 degree F. valve. Repeated attempts to make this joint tight by pulling up on the bolts had failed and had resulted in dishing the movable flange as shown in the lower half section of the drawing. To seal the leak three beads of weld were put around the flange as indicated. To correct the dishing of the movable flange a circular ring was put around the outside of the bolts and the bolts were pulled up until the flange straightened as in the upper half section of the drawing.

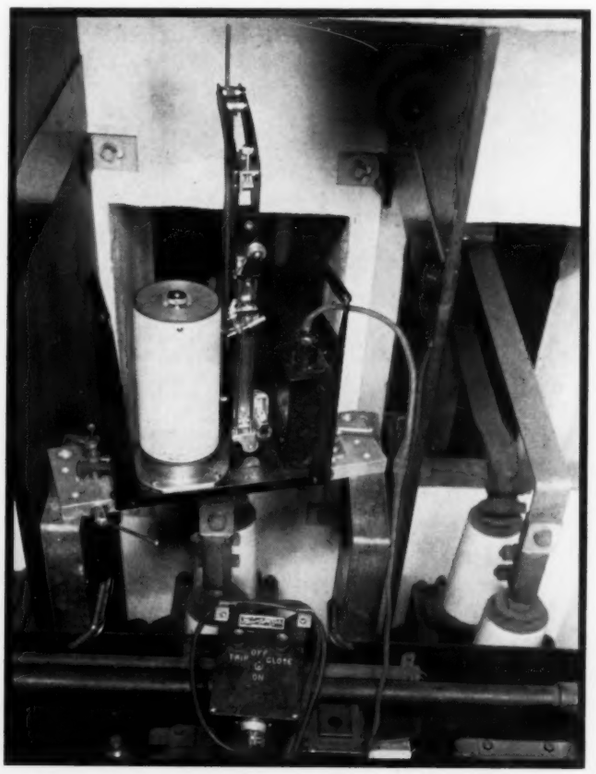
ELECTRICAL HELPS

The efficiency of any switch depends not only on the condition of the electrical parts but also the mechanical parts. To examine the mechanical operation of switches a "steam" indicator has been developed which looks very similar to a steam engine indicator. The apparatus develops a curve on a chart which is mounted on a drum. The drum receives its motion from a synchronous motor and the pencil receives its motion from the switch lift rod through a reducing motion. Figures 10 and 11 show the travel device mounted on oil switches. The chart and pencil are readily discernable.

Figure 12 shows a chart from the travel device. The mechanical faults shown on this chart are readily recognized. The oil dash pots were empty resulting in over

FIGURES 10 and 11—Views showing application of travel indicating device used for checking. (Below and Right)





travel and rebound. This condition was corrected and the dotted curve is the result.

Other conditions which the travel device will show are:

1. The condition of the latch assembly—whether it is worn or there is too much friction present.
2. The speed of the movable contacts—there is an exact speed for maximum efficiency of arc quenching. Too fast a speed may cause the arc to jump to other parts of the switch. Too slow a speed may cause excessive gas generation resulting in an explosion.
3. Shock absorbers, dash pots and buffers should also be adjusted properly to perform with maximum efficiency.
4. The closing mechanism should also be in proper adjustment for fast and smooth travel of the movable contacts.

We now have seven of these travel devices. They are equipped for switches having a travel of up to 56 inches. A chart is made before and after each switch is overhauled and this record is kept until the next inspection.

Rotating electrical equipment such as generators and frequency changers which do not operate in a self enclosed system require a periodic cleaning of the field, armature and laminations. The period of cleaning varies with the amount of dust and dirt in the surrounding atmosphere and is usually done about once a year. The old method of cleaning was to remove the end bells of the machine and to blow everything in sight with compressed air. This meant usually that the room was contaminated with the dirt from the machine being blown and it was questionable as to whether or not at least half the dirt went into the other rotating equipment in the room. The new method of cleaning employs the familiar furnace and chimney vacuum cleaning system. The suction hose is placed in the machine, both end bells remaining in place. Two men enter the machine through manholes and blow with compressed air. The vacuum system removes the dirt. With the new method a 15,000 kw. machine can be cleaned in approximately half the time required by the old method.

High voltage bushings are carefully inspected for mechanical defects such as cracks, bad gaskets, poor connections, etc. They are also tested for electrical defects by a power factor test set. All bushings with a power factor above 3.5 per cent are investigated and if this value cannot be lowered by field cleaning it is replaced as soon as possible and brought into the bushing shop for complete rebuilding and modernization.

Bushings are given complete reconditioning both mechanically and electrically. Mechanical improvement is due to general cleaning and replacement of gaskets, compound, nuts and bolts and general repair to make the assembly oil- and moisture-proof. The electrical improvement is obtained by proper heat treatment, static grounding and corona stress rings to improve the power factor of the insulation. The power factor test is a measure of the electric losses in the bushing compared to perfect insulation with no losses. The test instruments measure very small values directly at 10,000 volts.

One important development is the combination gasket composed of 2 gaskets used as a unit, the outside sealing gasket of cork. The rubber gasket is ½ the thickness of the cork. Another important change is the

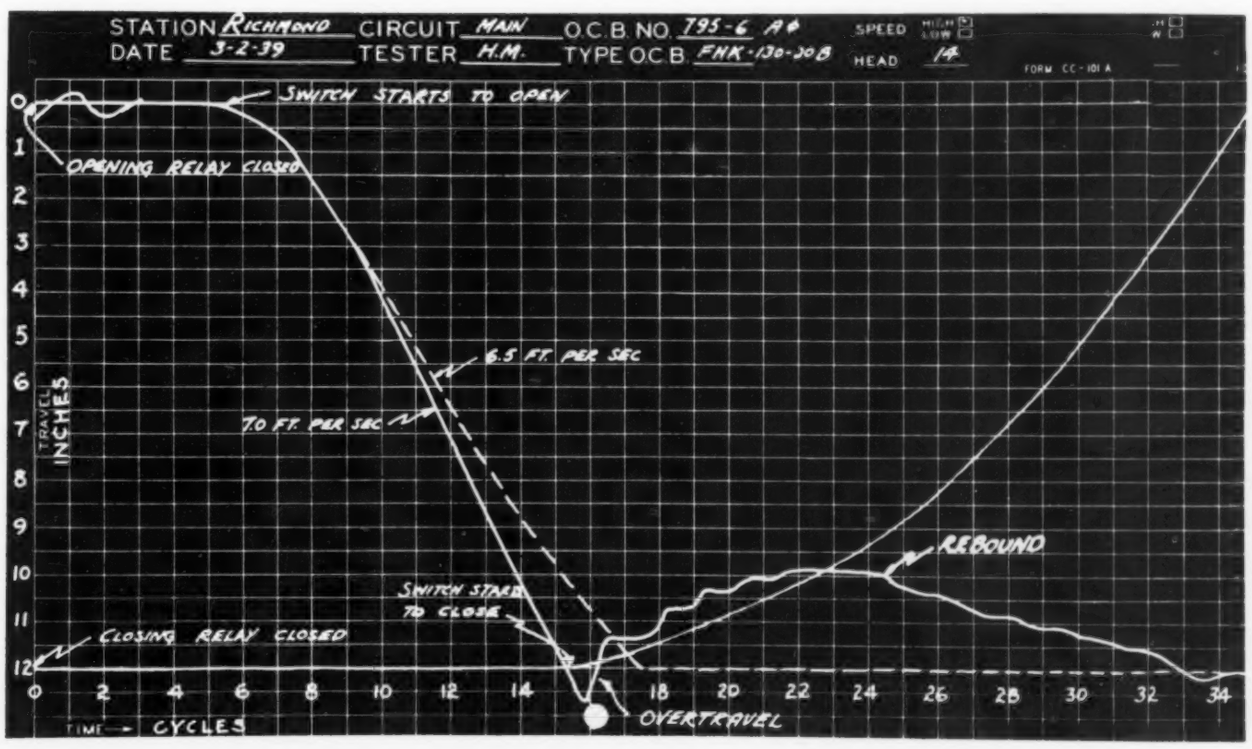

STATION Richmond CIRCUIT Main O.C.B. NO. 795-6 A ϕ SPEED
DATE 3-2-39 TESTER H.M. TYPE O.C.B. FHK-130-208 HEAD 14
FORM CC-101 A
SWITCH STARTS TO OPEN
OPENING RELAY CLOSED
6.5 FT. PER SEC
7.0 FT. PER SEC
TRAVEL INCHES
REBOUND
SWITCH STARTS TO CLOSE
CLOSING RELAY CLOSED
OVERTRAVEL
TIME — CYCLES
0 1 2 3 4 5 6 7 8 9 10 11 12
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34

FIGURE 12—Sample chart from testing device shown in Figures 10 and 11, indicating faults in switch operation.

replacement of the old style one-piece top assembly to a two-piece top assembly. The new assembly makes the gasket accessible for inspection and replacement as well as facilitates the inspection of the compound.

These two items are but a few of the many developments such as methods of using new paper insulation for rebuilding of obsolete or scrap bushings, varnish and gasket materials, special modernization features for old bushings and oil- and moisture-proofing the bushing core.

SAFETY HELPS

Metal tubular scaffolding has entirely replaced wood for temporary structures. It is used because of its greater economy, durability and dependability, and it eliminates the large amount of wood which would eventually become waste. Wood is used as platform and steps only. The tube scaffolding is conveniently stored after use and reused indefinitely. It is easily erected and is fool-proof. It is probably one of the major safety practices that we have adopted in several years.

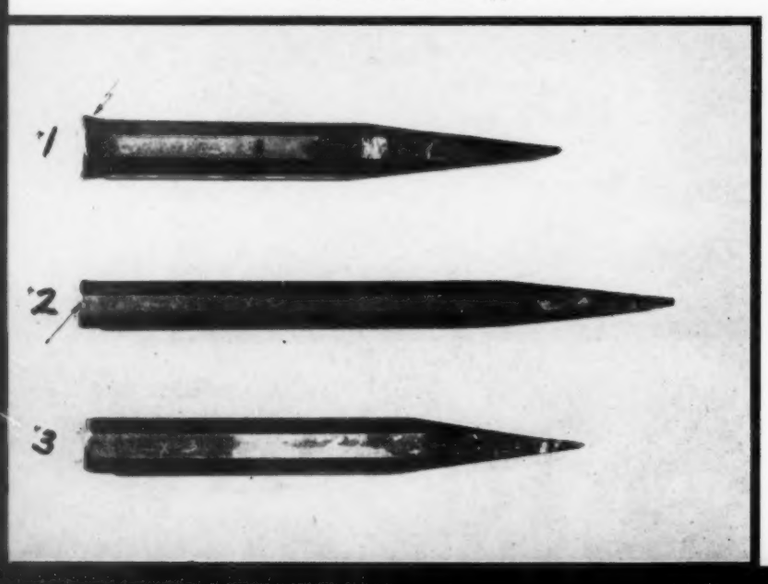
The question of chisels and chisel material has been a serious problem. With various people purchasing different steels and having these tools dressed by the nearest or most convenient blacksmith the results were never uniform and use of the tools was hazardous. With this thought in mind and to check on our present shop practice two chisel materials were obtained and tested against our standard chisel material which is fabricated and heat treated in our own shops. The results of the tests are shown in Figure 13.

Chisel No. 1 is a non-tempering tool steel sold commercially. (Forged at 1900 degrees F., quenched in water from 1700 degrees F.). Tank steel ¼ in. thick was cut with this chisel and 1100 blows were struck with an 11 lb. sledge. Note the mushroomed head.

Chisel No. 2 is sold commercially ready for use. It was tested the same as No. 1. After 648 blows were struck the test was stopped. Note the cracked head.

Chisel No. 3 was fabricated in our own shops from our standard chisel material. It was forged at 1700 degrees F., normalized at 1600 degrees F., the entire chisel quenched in oil from 1550 degrees F. and tempered at 360 degrees F. for two hours. After 1100 blows there was no sign of failure.

FIGURE 13—View showing results of duplicate tests applied to three different types of chisels.



Results of this test proved two things: first, that our present shop practice produces a chisel far superior in service to the commercial chisels used for comparison; second, that all chisel materials should be purchased and heat treated with the proper knowledge of steels and heat treatment.

DISCUSSION

PRESENTED BY

W. H. BEYERLE, Assistant Electrical Superintendent, Bethlehem Steel Company, Sparrows Point, Maryland.

W. F. OBERHUBER, Superintendent of Maintenance, Philadelphia Electric Company, Philadelphia, Pennsylvania.

W. H. BEYERLE: The problem of maintenance in a steel plant is a never ending one. Every plant must plan its maintenance work according to its needs and different plants may employ different methods but ultimately all must reach the same objective. The inspection of electrical equipment, for instance, should be done frequently, depending on the service and it should be sufficiently thorough to assure its continuance in service until permanent repairs can be made. We cannot in every case anticipate when equipment might fail but we do try to make regular inspection toward that end.

The cleaning of machines was mentioned by Mr. Oberhuber. That sometimes is a difficult problem especially with open type machines operating in a dirty atmosphere. In this case it is hard to remove the dirt and often when using high pressure air, the dirt is jammed in places where it can do the most harm. In the more recent installations the larger machines are kept clean and cooled by the use of the so called closed system. In this system, the same air is used over and over again and is cooled by passing over a water or air cooled radiator. When operating under these conditions, the windings do stay clean and frequent cleaning is then not necessary. If this scheme is employed, how often is inspection of the winding done? And if not employed, how frequently do you find it necessary to use insulating paint?

W. F. OBERHUBER: The closed systems of course are of the later type. The older type open ventilating system requires cleaning once a year. The vacuum method is only used on this type of machine.

We do very little painting on windings once the machine has been installed. We find it almost impossible when cleaning machines to remove all the dirt, and the painting of the windings just simply embeds the dirt in insulating paint and reduces the ventilating area. We have found the practice of not painting to our advantage. There is, however, an advantage in painting particularly where atmospheric conditions are such that it would be harmful to the windings, but where there is a clean atmosphere I do not see any advantage.

W. H. BEYERLE: Do you use the megger for insulation tests?

W. F. OBERHUBER: Yes, quite frequently.

A. I. & S. E.
Educational Committee Report

By H. G. R. BENNETT, National Chairman

▲ THIS year your Association has again awarded to each of the six district sections of our organization the sum of $1000 to be expended on educational projects of their own choice. The following is a brief resume of the work done and contemplated by the various sections.

BIRMINGHAM DISTRICT SECTION

For the first year the Birmingham district section awarded a scholarship to Robert B. Oliver who elected to perform research work relating to slag analysis, the work to be done at the University of Alabama. Another award was made to James A. Townsend, who elected to perform research work relating to methods of determining the hardness of light gauge sheet steel. This work was done at the Alabama Polytechnic Institute, and the resultant thesis was published in the September issue of the IRON AND STEEL ENGINEER.

The educational committee in Birmingham is now considering the formation of a lecture course similar to that conducted in the Chicago district last year.

CLEVELAND DISTRICT SECTION

The Cleveland district section last year conducted and elementary lecture course on electricity which was attended by foremen, sub-foremen and men under them. Classes were under the supervision of professors from the Case School of Applied Science. The average attendance at these classes was approximately 88 per cent.

Due to the popularity of this course and the great number of new requests to take the course, the Cleveland section repeated the same course for its second year program.

CHICAGO DISTRICT SECTION

The Chicago district educational committee last year established a lecture course covering the principles of iron and steel production. These classes were held in East Chicago, Indiana, and were held once each week. They were well attended and the project was considered to have been very successful, the average attendance being 90 per cent. The classes were composed of men varying in age from 20 to 55. The positions of men in the classes varied from men just starting in mill service to department superintendents.

No definite plans for the coming year have as yet been submitted to the national educational committee, but a similar plan with some slight modification to last year's, is being contemplated.

DETROIT DISTRICT SECTION

The Detroit district section last year decided upon a plan whereby it was arranged to allot the sum of $250 to each of four young men to assist them in pursuing their studies at the University of Detroit, Wayne College and the University of Toledo.

The manner in which these young men conducted themselves and the scholastic standing of each was sufficiently high that the Detroit district educational committee recommended that the same amount be awarded these same men for another year. This recommendation was approved by the national educational committee.

PHILADELPHIA DISTRICT SECTION

The Philadelphia district section last year awarded $1000 to Robert K. Kulp who did considerable research work on the woody fracture of steel to determine cause, significance, etc. Mr. Kulp has submitted a review of the work already done by him along these lines. The Philadelphia section committee thought the subject of sufficient importance to warrant the awarding of a like sum to be expended this year to finance a continuance of this work. This has been approved by the national committee.

PITTSBURGH DISTRICT SECTION

The Pittsburgh section educational committee last year placed their $1000 allotment into a student loan fund which was made available to worthy students at the Carnegie Institute of Technology. Reports have been received from this institution showing how the fund has been administered. As the loans are paid, the amounts will be made available to other students for years to come.

This year the committee awarded a scholarship to Richard Bundy of Steubenville, Ohio. $350 was given him for use in his freshman year at the Carnegie Institute of Technology, $250 will be loaned to him at 5 per cent interest for his second year, $200 will be loaned to him for his third year and the same amount for his senior year.

The Educational committees of all the district sections are to be congratulated upon the success with which they have performed their duties in assisting the Association in this endeavor.

RELAY Protective Steel Mill

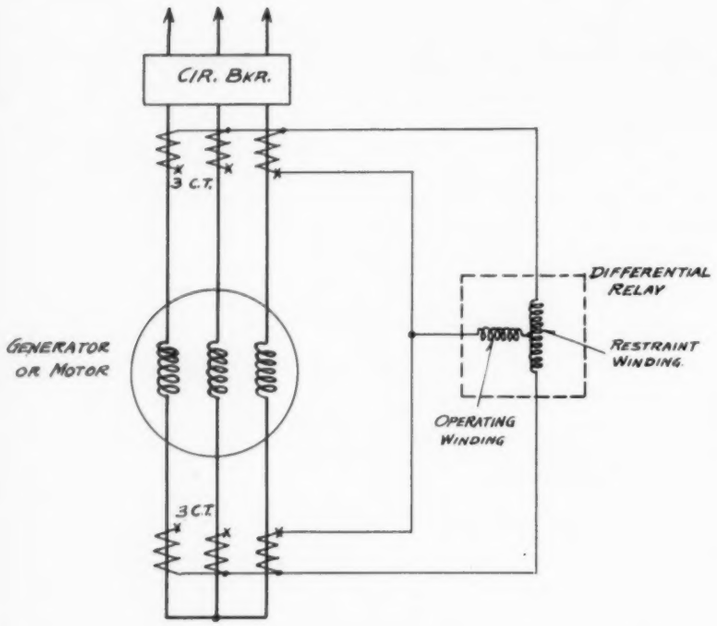


FIGURE 1—Schematic diagram for simple percentage differential relay protection applied to a motor.

▲ THE continued and increasing use of larger and greater numbers of synchronous motors in steel mills requires more consideration of the protective measures used, both from the individual motor and system standpoint. This is further emphasized by the fact that often the power supply is a large external system or a combination of a local plant generating station in parallel with a public utility system.

For this reason, this paper will be confined to a discussion of the protective measures most commonly used for large capacity motor drives. Particular reference will be given to synchronous motors because their characteristics introduce certain problems not common to induction motors.

Let us review briefly the several hazards to which a motor may be subjected and for which protective devices may be justified. Among the many abnormal operating conditions may be mentioned the following:

Short circuits in the motor.
Short circuits external to the motor.
Unbalanced current operation.
Overheating of windings.
Overheating of bearings.
Loss of field.
Undervoltage applied to the stator or armature.
Loss of synchronism.
Transient overvoltage.

Machines in steel mills are usually under the supervision and control of station attendants so that automatic tripping for all of the abnormal conditions may not be required, but certainly with the multitudinous duties assigned to the station attendants, suitable alarms may be well justified for those abnormal conditions that develop with relative slowness. In this way valuable equipment and loss of steel production may and can be minimized.

SHORT CIRCUIT PROTECTION

Obviously, certain types of abnormal conditions, such as short circuits in a motor, usually develop quite rapidly, and to save the machine from cumulative damages in itself and to relieve the system and restore general service, it should be promptly isolated from the system. As is well known and recognized, percentage differential relay protection affords prompt clearing of a short circuit in a machine at current values well below normal load values, and when properly applied is insensitive to external faults on the system. In the latter case of course, the synchronous motor reverses its action and functions as a generator due to the stored mechanical energy in the rotating parts and the stored electrical energy in the field of the motor. This "back feed" may be several times full load current, depending upon the reactance of the machine and the external impedance to the point of fault on the system.

The percentage differential relay with a 10 per cent slope adjustment, and connected to normal design current transformers is usually insensitive to this "back feed" and will not trip the motor from the system. Differentially protected motors require that both ends of each phase winding be brought to the motor terminal board so that current transformers may be connected to each end of the phase windings. The secondaries of the current transformers for each phase winding are then connected to the percentage differential relay. Figure 1 shows a schematic diagram for a percentage differential relay applied to a motor. For simplicity, only one phase of the three-phase Y-connected motor and leads to the circuit breaker are indicated. The remaining two phases are connected in a similar manner. It is more or less standard practice to have motors rated 1000 kva. and above, and 2200 volt and higher,

METHODS for SERVICE

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provided with the necessary leads for differential protection. Machines of lower rating both in kva. and voltage, can also have the proper lead arrangement when so ordered. It is considered good practice to have all motors that operate from the same bus differentially protected, if some of them would normally be so protected.

Relatively small motors can be protected by instantaneous over-current relays, set above the maximum "back feed" current that they can deliver, where the system can deliver more than the particular motor's maximum "back feed". This less expensive protection of course, is not sensitive to incipient faults in the motor winding, and greater damage to the armature must be expected. In fact a high value of fault current may and probably will cause burning of iron laminations, thus materially increasing the cost of repair and length of time the motor may be out of service. Broadly speaking, it is better insurance to provide for differential protection except for the very small and relatively unimportant motors. The percentage differential relays have established a most excellent service record in preventing serious burning of the iron laminations, thus eliminating the necessity of restacking the iron. These relays have also limited the damage to a very few coils

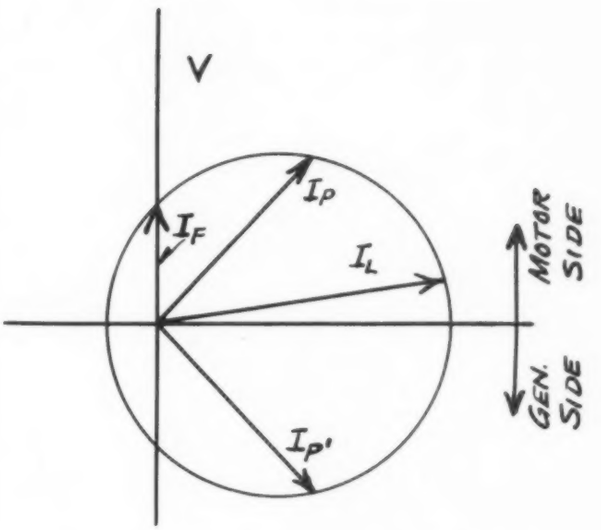
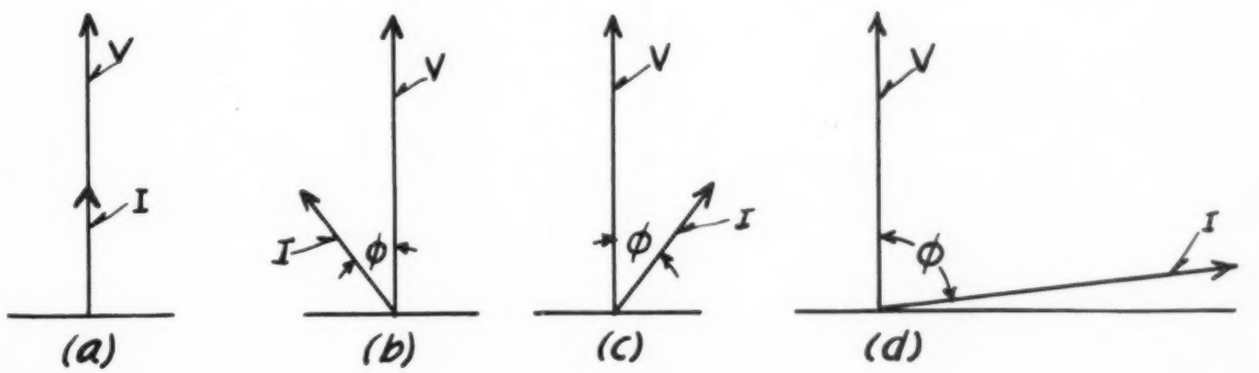


FIGURE 3—Diagram of motor current characteristics for the many conditions of machine operation.

FIGURE 2—Simple vector diagrams showing variation of power factor with load of a synchronous motor.



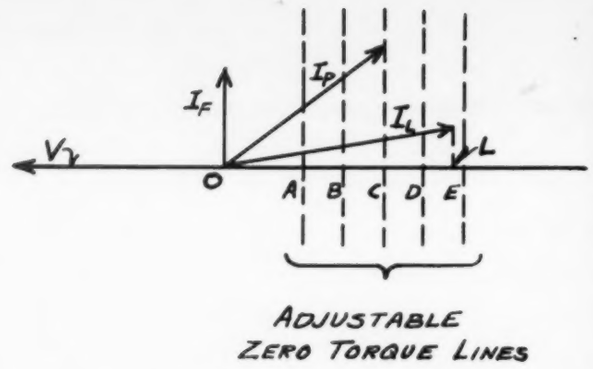


FIGURE 4—Torque characteristics of an induction watt relay presented in vector form.

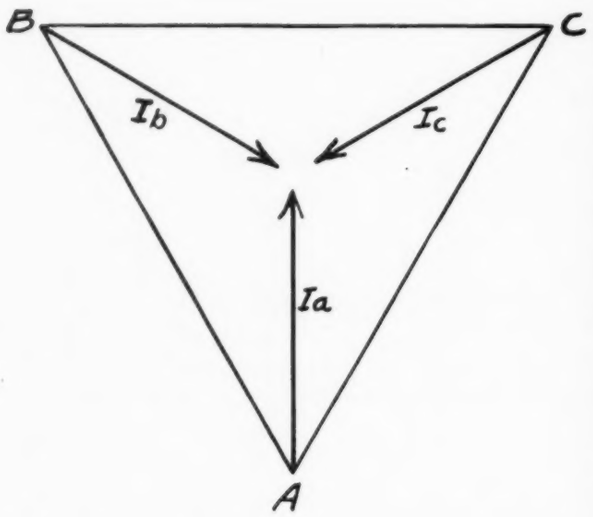
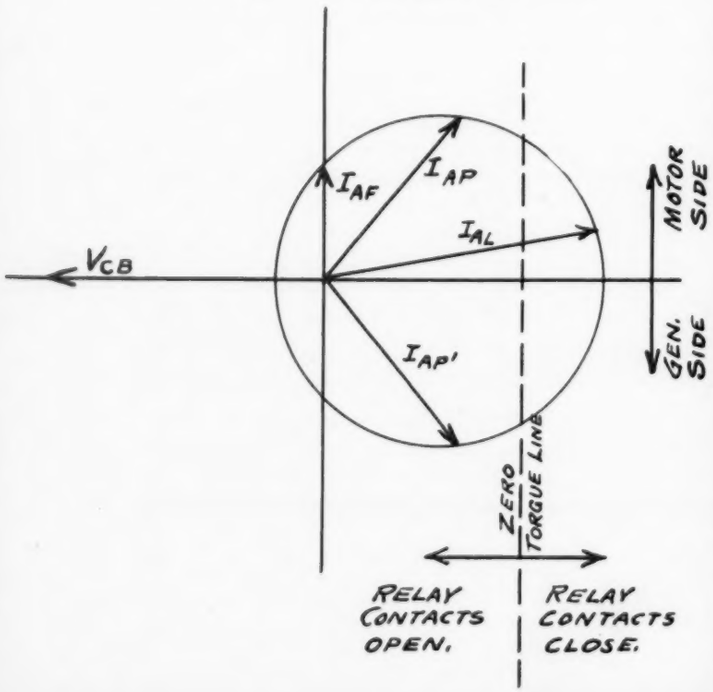


FIGURE 5—Vector diagram of three phase system, showing voltage and current relations at unity power factor.

FIGURE 6—Diagram combining Figures 3 and 4, showing performance of power factor relay.



and have largely nullified the fire hazard of burning insulation. Whenever electrically tripped field switches or circuit breakers are provided as part of the motor control, the differential relays are arranged to trip it, as well as the line breaker. If the neutral of the machine is grounded, a neutral breaker should be provided and tripped simultaneously with the main and field breakers.

UNBALANCED CURRENT OPERATION

This phenomenon may be caused by an open circuit in one phase of the supply circuit to the motor, or to a lesser degree by one or more short circuited turns of a phase winding in the armature of the machine. (The latter condition will not be recognized by the usual differential protection which balances the current entering a phase winding against the outgoing current of that same phase winding.) If the unbalanced motor currents are prolonged, especially in case of an open circuit in one phase either external or internal to the motor, severe overheating will result and the machine windings may be roasted out and bad short circuits develop. To recognize such a condition at the start and give adequate warning either by alarm or tripping the machine from the system, balance relays are now considered as standard protection for the more important motors in steel mill service regardless of size. These relays function when the percentage of unbalance between phases increases beyond a certain value usually on the order of 20 per cent of full load current. This form of relay responds promptly when the unbalance occurs and is superior to a thermal relay which must wait until sufficient abnormal heating has developed before it can function.

OVERHEATING OF WINDINGS

Since many steel plant motors, particularly those used for main drives, are subjected to a widely fluctuating load, their nominal continuous current rating has been based on a particular reoccurring load cycle. The root mean square current demand for a prolonged cyclic period is assumed not to exceed the root mean square current of the continuous current rating of the motor. If, due to unforseen conditions, the load cycle is increased, then overheating of the motor must be expected. Means should be provided to give adequate warning of such conditions in the motor, and thus allow measures to be taken to relieve the motor of its sustained overloading in order to prevent burn-outs or too rapid deterioration of the insulation.

For motors of 1000 hp. and above, temperature relays operating from embedded resistance temperature coils or detectors gives the most sensitive protection. This is because the relay will function according to the temperature at the location of the detector coil regardless of what causes the heating. These detector coils are usually located between the upper and lower coil in the armature slots, where there is the least ventilation, and thus respond to the "hot spots" in the motor. In order to obtain the "hottest spot" several sets of detector coils are usually provided in a given

machine, and by actual test, the coils giving the highest temperature reading under load are used in conjunction with the temperature relay.

For the smaller motors that cannot be satisfactorily or economically equipped with temperature coil detectors, replica heating relays are commonly used. These relays received current proportional to that at the machine terminals and the time-lag heat storage of these relays is approximately that of the time-lag heat storage of the motor, provided the ambient temperature at the relay location is reasonably close to that of the motor location.

Both types of relays usually have the contacts actuate an alarm system rather than trip the motor off the system. Occasionally an auxiliary timing relay may be used to clear the motor from the system in order to circumvent an overly ambitious production enthusiast.

OVERHEATING OF BEARINGS

Protection against overheated bearing is now quite common practice for the larger machines in steel mill service. It is usually of the thermo-sensitive bulb type in direct contact with the bearing metal. Occasionally a temperature relay using the embedded coil detector is used. When bearings start to overheat their temperature rise is usually quite rapid and the machine must be taken out of service rather promptly. In several recent installations an alarm is first sounded and then, within a short time, the machine is tripped off the line unless the attendant has been able to cool the bearing promptly.

LOSS OF FIELD

Protection for this rather infrequent condition is usually taken care of by the same relay that provides for "pull-out" protection, which will be subsequently discussed in some detail. Occasionally in attended stations, and usually in unattended stations, a d-c. current relay having a low drop-out characteristic and time delay either inherent or by auxiliary means is provided. Such a relay must be capable of carrying current proportional to the maximum sustained field of the particular motor, yet not close its contacts unless the field current is below no-load value.

UNDER-VOLTAGE PROTECTION

Such protection has been in use for years and its justification is obvious. However, many of the older equipments are of the so-called instantaneous type which will give unnecessary shut-downs. Modern practice has well established the correctness of time delay under-voltage protection either by direct acting devices or quite commonly by an induction under-voltage relay, especially in the larger installations involving electrically operated breakers. Such time delay prevents shutdown due to momentary voltage dips, the frequency of which materially increases with the extent of the electrical system. This is particularly true where purchased power is received from systems covering a large area.

PULL-OUT PROTECTION

Many of the recent important motor drives in steel mills are being provided with a so-called "power factor" relay. This relay is an induction type wattmeter element with its current and voltage connections so related that the contacts tend to close only when excessive low lagging power factor current (approaching the locked rotor current value) is drawn by the motor. During the motor starting period the tripping circuit is kept open, and after the motor is operating normally an auxiliary timing relay establishes the tripping energy source to relay so that it may function if called upon. Since the adjustment of this relay is such that it will not function unless this pull-out value of the machine is exceeded, it gives protection against loss of field (under load conditions), motor pull-out, and out-of-step or "hunting".

It may be of interest to review the armature current characteristics of a synchronous motor under various normal and abnormal operating conditions, with relation to the operating characteristics of this relay. A few simple vector diagrams showing the relation of the voltage and current of one phase winding of a motor will probably be the best method. The usual standard counter clockwise rotation of vector is used, to show the phase relation between them, while the length of the line representing the vector is proportional to the magnitude of the quantity. Assuming a synchronous motor to be operating at normal voltage, rated load, and unity power factor, then the phase to neutral voltage vector and armature current will be superimposed on each other as indicated in Figure 2a. If the motor load is reduced and the field current remains unaltered, then the machine is relatively over excited and Figure 2b would represent the phase relations, i. e., the current is leading the voltage vector by some angle. However, if the motor becomes overloaded and the field current is not changed, the machine is relatively under excited and armature current lags the voltage, Figure 2c. As the overload increases, the power factor or angle of lag between the phase voltage and current becomes greater and the magnitude of current increases until the motor stalls and locked rotor current is drawn at a very low power factor as in Figure 2d.

If a curve is drawn through the ends of the current vectors for the many conditions of machine operation both as a motor and momentarily as a generator, it will take the general form shown in Figure 3. The portion of the current locus curve above the X-axis represents the machine acting as a motor while that part below the X-axis shows generator characteristics. The relative magnitude of this current locus of course depends upon detail design characteristics and the relation of pull-out torque with respect to normal full load rating. It will be observed that the current locus is nearly a circle whose center is materially off set from the pivot point of the voltage and current vectors. Several current vectors have been indicated such as unity power factor full load current (I_f), motor pull-out current (I_p), motor locked rotor current (I_l), and pull-out current as a generator (I_p^1), It will be noted that the pull-out current as a motor and as a generator have

practically the same scalar value and the angle with reference to the X-axis is substantially the same, but 90 degrees from each other. The pull-out current as a generator is of course leading with respect to the generated voltage because of the relative under excitation for loading beyond unity power factor full load excitation.

Figure 4 shows the torque characteristics of an induction watt relay drawn in vector form. The several zero torque lines represent variations in spring tension given the moving contact, thus requiring a definite watt torque to close the relay contacts. The convention of having the voltage vector 180 degrees from the current vector for maximum closing torque is common practice.

With no spring tension the zero torque line passes through the focal point of the vectors, and if the current leads or lags the applied voltage by 90 degrees there will be no contact movement. As the spring tension is increased from A to E, more and more lagging current with respect to vector I_f will be required to cause the relay contacts to close, as only the component of current 180 degrees from the applied voltage causes the closing torque necessary to overcome the particular spring tension adjustment. Thus a lagging current of value I_l has a component OL^1, giving this relay a torque greater than a spring adjustment corresponding to a current equal to OD 180 degrees from voltage OV.

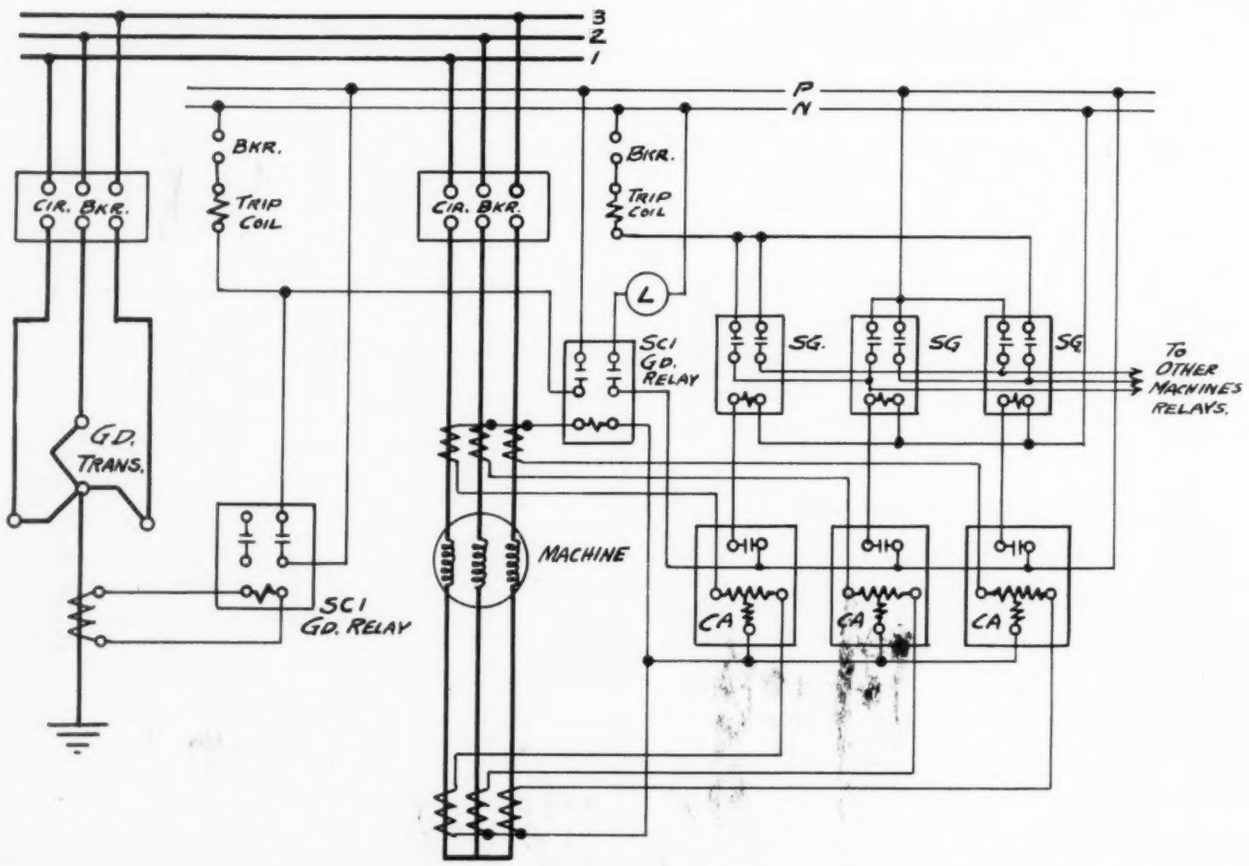
It will be observed that current vectors I_f, I_p and I_l have the same relative phase position and magnitude as those in Figure 3 which represents full load unity power factor current (I_f), motor pull-out current (I_p) and locked rotor motor current (I_l). By choosing a voltage applied to the motor so that it leads the full load unity power factor current by 90 degrees, the power factor relay can have its spring tension adjusted so that the contacts will not close unless the motor has pulled out of step and the current value approaches locked rotor value. This is easily accomplished.

In Figure 5 we have a vector diagram of a three-phase system showing the three phase-to-phase voltages and the three unity power phase currents going to the motor.

Figure 6 is a combination of Figures 3 and 4, using I_a and V_{bc} from Figure 5. From this figure the performance of the power factor type relay, when applied to a synchronous motor, can readily be visualized.

With such a connection the relay will only trip when the machine pulls out of step due to relative under-excitation. As previously mentioned, an auxiliary

FIGURE 7—Schematic diagram of relay application requiring a double line-to-ground fault before tripping.



timing relay is required during the starting up of the motor, as locked rotor current is initially drawn, and the trip circuit must be kept open until the current has died down below the tripping value of the relay.

It will be further observed that during the transient period of short circuits external to a synchronous motor, the generator action of the motor produces a current on the non-tripping side of the relay, until the motor falls out of step due to using up all of its stored energy. If the external fault has not been cleared by that time, it is necessary to take the motor off of the system and restart it when normal conditions have been restored.

GROUND PROTECTION

In the past, the majority of steel mill electrical distribution systems have operated with the neutral isolated. Within the past few years many of the larger systems have grounded the neutral of their main supply systems. This necessitates the immediate clearing of the grounded portion of the system. Some operating departments have felt that main drive motors should not be tripped while steel is going through the rolls. To meet this requirement, the source of ground current, usually a relatively small grounding transformer, has been immediately isolated by opening its breaker through the action of an instantaneous over-current relay energized from a current transformer in the neutral lead. The various motor and feeder circuits are also equipped with quick acting ground relays. These relays, however, do not trip their associated breaker but merely sound an alarm and show a target, thus identifying the portion of the system that has developed a ground.

Where sensitive differential relays are used for motor protection, they must be wired through auxiliary interlocking relays to prevent tripping the motor in case of a single line-to-ground fault. This interlocking is so arranged that if a double line-to-ground fault occurs, either in a single motor or between two motors, the differential relays are allowed to trip one or both motors as the case may be. This is of course necessary as a double line-to-ground fault is similar to a phase-to-phase fault on an isolated neutral circuit and the faulted portions of the system must be promptly cleared. Figure 7 shows a schematic diagram of one such system that has been in operation for some time. Many variations of this scheme are possible and have been put in operation. Their service record to date has been generally satisfactory.

Present-day designs of ground relays have a lower limit of 10 per cent of the current transformer ratio as the minimum satisfactory pick-up value of the relay. With induction relays predominating, it has been found that the minimum ground fault current that can flow through a particular circuit should be roughly three times the 10 per cent limit or 30 per cent of the current transformer ratio in order to obtain quick tripping. This means that in a straight radial distribution system, the size of the grounding transformer is dictated by the largest ratio current transformer on the system. Where parallel or loop system feeds are used, the size of the grounding transformers may have to be increased if the total ground does not pass through the largest ratio current transformer.

SURGE PROTECTION

Rotating machines, by the very inherent design, are not as well able to resist steep wave front voltage surges as are transformers. If an incoming steep wave voltage surge can have its slope increase and the crest reduced, the windings of motors can more readily absorb the surge before break-down point is reached. There is a decided trend to provide such protection to steel mill motor installation. The equipment usually consists of (1) special lightning arresters with a protective ratio of two, to limit the magnitude of lightning surges to ground, and (2) a capacitor to slope the steep wave

FIGURE 8—Diagram showing protective devices applied to a machine directly connected to a line.

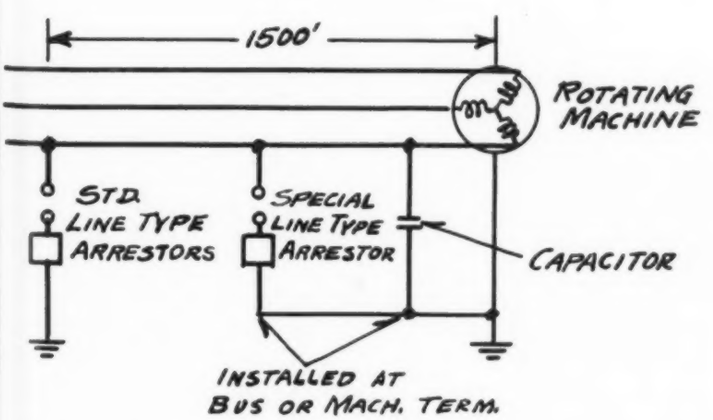
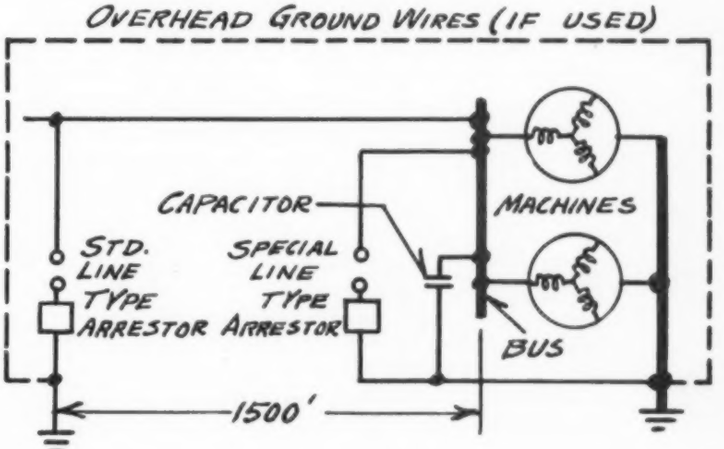


FIGURE 9—Single line diagram showing protective devices on a common bus feeding two or more machines.



front of the incoming surge so that the entering wedge of the wave is flattened. As the surge enters the motor winding it will tend to distribute itself throughout the winding and raise the potential of all coils more or less evenly, instead of "piling up" on the end coils of the winding. Standard lightning arresters are also recommended to be installed on incoming lines some 1500 ft. away from the station in order to limit the crest of the incoming wave.

Figures 8 and 9 are typical connection diagram for installing surge protection to either a single machine or several connected to a common bus.

There are, of course, other refinements or protection that may be warranted in individual cases, and all of the forms of protection discussed above are not always applied to each and every motor. An economic balance for each individual case should generally be the answer as to the extent of the protective measures to be provided for.

DISCUSSION

PRESENTED BY

L. A. UMANSKY, Steel Mill Engineer, Industrial Department, General Electric Company, Schenectady, New York.

J. B. LOONEY, Electrical Laboratory, Sheet Mills, Tennessee Coal, Iron and Railroad Company, Fairfield, Alabama.

F. O. SCHNURE, Electrical Superintendent, Bethlehem Steel Company, Sparrows Point, Maryland.

W. A. PERRY, Superintendent of Electrical and Power Departments, Inland Steel Company, Indiana Harbor, Indiana.

H. A. TRAVERS, Power System Engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

L. A. UMANSKY: Mr. Travers' paper brings out, very clearly and concisely, why the protective relay equipment for rotating apparatus is now more involved and rightly so, as compared with the days when two overload relays and one undervoltage relay were considered an ample protection. You simply value your equipment more, you want to give it more preventive protection.

I can subscribe to practically everything brought out by Mr. Travers, but believe that one or two points can be elaborated. The first point deals with protection against transient overvoltages. Mr. Travers, in his paper, considers only lightning as a cause of this disturbance. For such case one set of capacitors connected to the bus will protect several machines also connected to this bus. We know that overvoltages also occur during the switching operations; whenever the line potential is first applied to motor winding, this potential is not distributed evenly between the turns; sometimes as much as 80 per cent or more of line voltage is concentrated initially on the few turns next to the machine terminals. To prevent this occurrence, it has been suggested—and this suggestion has been successfully followed in practice—to connect capacitors at the machine terminals, or at any rate, at the motor side of the oil circuit breaker. Thus, you require as many sets of capacitors, as you have machines which you want to protect, rather than one set on the bus only.

Then, I can not fully subscribe to Mr. Travers' arrangement of ground protection. He contemplates, in effect, to isolate the normally grounded neutral in case of a ground fault developing somewhere on the system. In other words, a grounded neutral system is then lowered to the status of an underground system. Now, the fundamental purpose of neutral grounding is to give a better and fuller protection to the apparatus on the system. When trouble, such as ground fault, develops, it is the least opportune time to relinquish the available extra protection which the grounded neutral gives.

J. B. LOONEY: I don't know of anything that I can add to what has already been said about power factor relays. They did give us quite a bit of trouble when they were first installed. We had never seen anything like it before that time and they represented a new idea in protection. We didn't know what to do with them. Heretofore, we thought that when a motor was supplied with overload, differential and thermal relays, we had all the protection necessary. With the new power factor relays, we found that we had something which for a time gave us some trouble, due to the fact that surges on the line would kick out the station switch when there was nothing wrong with the mill or synchronous motor involved. A solution for this condition was our big problem.

I believe it has been well pointed out in the paper that the phase relation of the potential with respect to the current, was essential for the correct operation of this type relay. This relay will not function correctly when the voltage and current are in phase and the reason for this was clearly brought out by Mr. Travers in his paper. If you put the current and potential in phase the relay will bounce out every time there is a line surge or interruption anywhere on the system. That situation we found to be true by experience. We corrected it, with the advice and assistance of Mr. Travers and his company, by changing the phase angle of the current and potential to the relay.

There is another relay problem which we have that is a little different from the ordinary. A 75 horse power automatic pumping station protected by overload and phase balance relays, is frequently knocked out during remote switching on the system. The phase balance relay mechanically locks out during such switching and when an inspection of the equipment is made, nothing is found wrong with the motor or circuit. Since the station is about three miles distant, some considerable delay has been experienced by these uncalled for relay operations.

F. O. SCHNURE: We have protected transformer banks with differential relaying for a number of years with excellent results. About ten years ago we ran

into so much trouble from failures on oil soaked gas engine generator windings that we decided to put differential protection on these generators, which was no easy job, because they were parallel delta windings. Since that time, any troubles that do occur are snuffed out so quickly there is comparatively little damage done to the windings or to the iron.

Our practice on new work subscribes to unbalanced current protection, thermal protection of windings and bearings, loss of field and under-voltage protection.

In pull-out protection afforded by the power factor relay, we had the same weird experiences as mentioned by the gentleman who preceded me, however, Mr. Travers and his associates have helped us clear up this situation.

Our power system is served by 50,000 kw. generation, 37,500 kva. in 25 cycle and 50,000 kva. in 60 cycle purchased power capacity. The neutrals of the 25 cycle purchased power transformers are solidly grounded while the neutral of the recently installed 60 cycle system is grounded through a reactor designed to limit the fault current to 2000 amperes. The recently discovered relation between the value of reactance in the neutral and the reactance of the transformer bank and other physical conditions in the system which produces dangerously high transient voltages during successive clearings and restrikings of an arc across the contacts of a circuit breaker while interrupting a fault or short circuit has led us to install a shunted resistor across the reactor to remove this hazard to equipment.

We are following the trend in surge protection by installing capacitors on all new equipment and are taking steps in a gradual way to protect the old equipment in the same manner. Along this same line we have installed several experimental sections of ground line in which the conductor is shielded at an angle of not over 20 degrees from the vertical plane. This is an adoption of the policy of our local utility on high voltage circuits and whether it will be successful on our comparatively low voltage, 6600 volt circuits, remains to be seen.

W. A. PERRY: When Mr. Travers gets around to answering questions, I would like to know if they have gone into the protection of the synchronous motor during the starting period, especially in a case where a synchronous motor on a roughing stand should kick off and the operator of the mill, noticing that the drive has kicked off, immediately recloses the breaker with a slab in the mill, before it is up to speed and before the field has been applied?

H. A. TRAVERS: The discussion of this paper by various members of the Association has been most interesting and helpful. Mr. Umansky's contribution in connection with transient overvoltages should not be overlooked, because undoubtedly the use of capacitors for each machine gives added protection. Here again, as I pointed out in the closing paragraph of my remarks, it is a matter of economic balance as to how far an individual case should be taken.

Possibly my remarks with reference to grounding the neutral, and the scheme shown in Figure 7, has been misinterpreted. This sketch was presented to show what had been done in one or two instances where "grounding the neutral" was not whole-heartedly received. Since "half a loaf is better than none", the scheme shown was put into effect with the hope that later on the neutral would be permanently grounded. Apparently, here is a case of possible loss in production, versus the probability of failure in a main drive motor.

Mr. Looney and Mr. Schnure were, doubtless, among the first who came into contact with the use of the power factor relay for motor pull-out protection. Here was a case of a new application of an old fundamental relay. The characteristics of the circuit to be protected were not clearly visualized. Consequently, expected results were not obtained at first.

Mr. Looney's question regarding the action of the phase balance, relays in connection with an automatic pumping station motor, leads me to believe that the phase balance relay is tripping the breaker directly. It should preferably actuate an auxiliary timing relay so as to permit the external faults to be cleared by the circuit protective relays. This, because the synchronous motor acts as a generator at time of external fault, and delivers unbalanced current to the fault. This, in turn, causes the fast acting phase balance relay to close its contacts.

Mr. Perry's question, I assume, presupposes the use of an overcurrent relay, set low enough to trip a roughing stand motor, due to heavy peak load. It would seem that a little more time allowance would permit the relay to "ride through" the relatively short time peak load, typical of such motors. If, for any reason, the motor did stall with a slab in the rolls, and the operator closed in the breaker a second time, it would be tripped out within a relatively short time, say four or five seconds.

A. I. & S. E.
November Meetings

PHILADELPHIA DISTRICT SECTION
November 4, 1939

"Dust and Fume Problems in Industry," by J. S. Rogers, *Industrial Hygienist,* Division of Labor Standards, U. S. Department of Labor, Washington, D. C.

"Safety Fuel Engineering," by C. E. Duffy, *Assistant Fuel Engineer,* Bethlehem Steel Company, Sparrows Point, Maryland.

CHICAGO DISTRICT SECTION
November 9, 1939

"Experiences in Holland," by Gordon Fox, *Vice-President,* Freyn Engineering Company, Chicago, Illinois.

DETROIT DISTRICT SECTION
November 14, 1939

"The Better Side of Industry—Safety," by A. A. Nichoson, Texas Company, New York, New York.

PITTSBURGH DISTRICT SECTION
November 20, 1939

"Modern Maintenance Practice," by T. R. Moxley, *General Master Mechanic,* Wheeling Steel Corporation, Steubenville, Ohio.

BY-PRODUCT FUELS

...in the Steel Industry...

By GORDON FOX, *Vice President and*

W. B. CLEMMITT, *Chief Engineer*

FREYN ENGINEERING COMPANY, Chicago, Illinois

Presented before the A. S. M. E.
New Orleans, La., February 23, 1939

▲ APPROXIMATELY 37 million tons of pig iron were produced in the United States of America in 1937. To produce metallurgical coke for this operation, it was necessary to coke about 54 million tons of coal. The total gases resulting as by-products from these operations had a heat content equivalent to about 32 million tons of coal. If the screened-out coke breeze and the tar be added, the total potential by-product fuels resulting from steel plant operations amounts to some 35 million tons coal equivalent. This is equal to about 7.5 per cent of our national coal consumption. The effective use of these by-product fuels is obviously a matter of some import.

The principal by-product fuels of the steel industry, with an indication of their relative heat content in a balanced plant, are as follows:

Blast furnace gas	55	per cent
Coke oven gas	35	
Coke breeze	6.5	
Tar	3.5	
	100.0	per cent

The two last-named fuels are not discussed in this paper.

While there is a wide range in the quantity and the heating value of the gas delivered from an individual oven during the coking operation, dependent upon the time elapsed since charging, the product from a battery of ovens which are charged in sequence, is very uniform. Changes in the coal mixture may affect both the gas quantity and analysis. Changes in coke production rate, effected by varying the coking time, affect the rate of gas production correspondingly. Such changes are infrequent. The operation is continuous 24 hours per day and 7 days per week.

GORDON FOX

COKE OVEN GAS

Coke oven gas contains about 25 per cent of the heat value in the coal from which it is produced. Derived by releasing the volatile content of coal by heat in the absence of air, it comprises principally hydrogen and hydrocarbons, and is low in carbon monoxide, carbon dioxide and nitrogen. After being exhausted from the ovens, it is treated for removal of by-products. Extensive cleaning operations are essential to by-product recovery. The resulting product is a relatively clean gas of about 520 Btu. per cu. ft., delivered substantially saturated with water vapor, at atmospheric temperature and gas holder pressure.

Coke oven gas is delivered either from the holder or from the supply line to boosters, which increase the pressure for distribution. For use at the bulk consuming units in the steel works, the gas should be delivered at a pressure of at least 5 lb. per sq. in. Small consumers, such as normalizing furnaces, commonly require pressures from 5 to 10 lb. per sq. in. It is customary practice to boost the gas for these uses in local com-

pressors to a pressure between 15 lb. and 20 lb. per sq. in.

Coke oven gas burns with a transparent but rather white flame, which tends to be somewhat buoyant. It requires theoretically about 5 cu. ft. of air per cu. ft. of gas for perfect combustion. Very little excess air is required in practice due to the high ratio of air to gas and the consequent intimacy of mixing. The flame is characteristically short. The gas will hold ignition temperature under less favorable conditions than most industrial gases, because of the high flame temperature and rapid rate of ignition. Coke oven gas is not commonly preheated, as any substantial preheat (in excess of 500 degrees F.) causes the hydrocarbons to break down, resulting in deposition of carbon in regenerator or recuperator chambers.

BLAST FURNACE GAS

Blast furnace gas contains about one-half of the heat value in the coke charged into the blast furnace. The analysis, heat value and top temperature of blast furnace gas differ according to the kind of iron or ferrous alloy being produced. The heat value usually ranges between 85 and 100 Btu. per cu. ft. For a given operation, the analysis is not entirely uniform, a range of plus or minus 5 per cent in heat value being typical. Blast furnace operations are subject to delays ranging from 5 minutes to an hour or more, incident to tuyere changes and other operating emergencies. During such periods, gas production is discontinued. The rate of blowing may be varied over a wide range to suit production to demand. About once in three years a furnace must be blown out for relining and repairs, which consume about two to three months. Since most plants have but a few blast furnaces, the shutting down of one furnace deducts substantially from the production of gas. The trend toward larger blast furnaces accentuates this condition. In general, it may be said that the supply of blast furnace gas is subject to much wider variations than the supply of coke oven gas.

Due to its bulk, it is not ordinarily considered feasible to store large quantities of blast furnace gas. A 10,000,000 cu. ft. gas holder contains only about two hours gas output of one 1000-ton blast furnace. Consequently it is necessary to adjust the consumption of blast furnace gas to the supply.

Blast furnace gas leaves the top of the furnace at a temperature between 250 and 700 degrees F., and at a pressure between 15 in. and 60 in. of water. It has a dew point of about 120 degrees F., corresponding to a moisture content of about 30 gr. per cu. ft., this being contained in the blast and picked up from the burden which may be wetted to restrict top temperature and dust pick-up. It is generally cleaned in wet stationary towers to about 0.25 gr. per cu. ft., the gas leaving the towers saturated and carrying considerable entrained moisture. Improved towers with cyclone dust and moisture eliminators deliver saturated gas of about 0.1 gr. dust per cu. ft. Further cleaning may take place in rotary disintegrators or in electrical precipitators. By these means the gas may be cleaned to less than 0.01 gr. dust per cu. ft.

Gas which is to be used to underfire coke ovens, and that intended for gas engine use, is generally cleaned to 0.01 gr. per cu. ft. or better. Gas which is to be used at open hearths and heating furnaces should not contain in excess of 0.05 gr. per cu. ft.

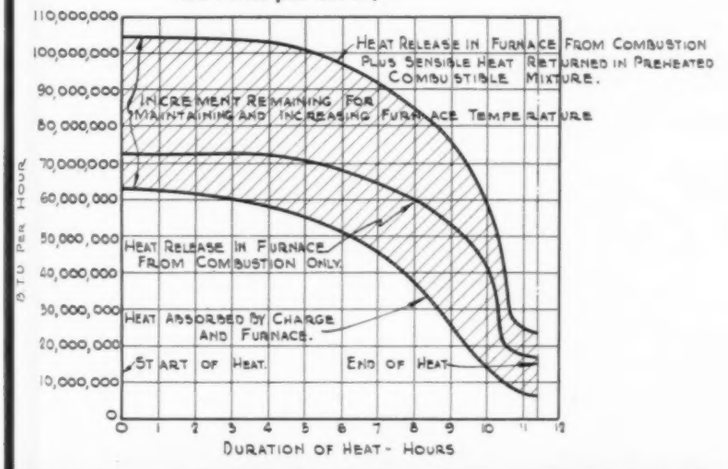
Blast furnace stoves can be designed with large checker openings (3.5 to 4 in.) to use gas having 0.25 gr. dust per cu. ft. Such stoves have efficiencies on the order of 80 per cent. Stoves having somewhat smaller checker openings (2.5 to 3 in.) can use gas having 0.15 gr. dust per cu. ft. Such stoves are about 85 per cent efficient. Stoves with small checker openings (2.0 to 2.5 in.) may be built to give 90 per cent efficiency. Such stoves require gas containing not more than 0.03 gr. dust per cu. ft.

Blast furnace gas is delivered from wet cleaning operations at a pressure as low as 1 in. or as high as 20 in., depending on the nature of the gas cleaning equipment and on the pressure required to effect distribution. The pressure at which the gas leaves the blast furnace may be sufficient to pass it through the several cleaning operations, transport it through distributing mains, and deliver it to consumers at a pressure of 2 to 6 in. water necessary for its utilization. In such event, the pressure is supplied by the relatively efficient blast furnace blowing apparatus. In other instances, a lower furnace top pressure is desired and it is necessary to boost the gas pressure for distribution to about 25 in. Due to its low heating value and low-pressure transport, blast furnace gas requires relatively large mains for distribution.

In summary: coke oven gas, usually containing the minor portion of the by-product gaseous heat supply, is uniformly available. It is a clean gas having high heat content, suited to economical storage and distribution. It requires a relatively large volume of combustion air. It develops a high flame temperature and burns without luminosity.

Blast furnace gas is ordinarily the major by-product gaseous fuel. It is inherently dirty, bulky, not well

FIGURE 1—Chart showing variation in heat release and absorption during an open hearth heat (Fuel, 60 per cent blast furnace gas, 40 per cent coke oven gas 254 Btu. per cu. ft.).



suited to storage and distribution. It requires relatively little combustion air but develops a large volume of combustion products. It has a low flame temperature.

PROCESS CONSUMERS

Melting, refining, heating and heat treating are major steps in the production of steel. The cost of fuel for these operations is on the order of 15 per cent of the total cost of conversion processes. The steel plant affords a large market for its own by-product fuels.

COKE OVENS

For many years by-product ovens in steel plants have been underfired with coke oven gas. Most of the ovens constructed during recent years are adapted for underfiring with blast furnace gas. The operation is one involving relatively low temperatures, for which blast furnace gas is well suited (coke pushed at 1750 to 2200 degrees F.). Both the blast furnace gas and the combustion air are preheated. In order to prevent clogging of flues, very clean blast furnace gas is required, containing not to exceed 0.01 gr. of dust per cu. ft. The coking process is entirely continuous and there are no interruptions or substantial variations in gas use. Reliability of gas supply is essential, as stoppage of underfiring affects the quality of the coke, and expansion and contraction of refractories may lead to substantial injury to the oven structure. It is possible to change over from blast furnace gas underfiring to coke oven gas underfiring in an hour or less, but several hours may be required to adjust operations satisfactorily to the change. Therefore, frequent change-overs are undesirable. No provision is usually made for firing of auxiliary fuels, but ovens are given first preference as to gas supply, and precautions may be taken, such as providing gas holder storage.

BLAST FURNACE STOVES

The moderate temperatures required (air blast temperature 1000 to 1500 degrees F.) can be obtained from blast furnace gas without preheat of either gas or air. Great reliability of gas supply is not essential. If a blast furnace is not being blown, stove heating is unnecessary. The refractories in blast furnace stoves can store considerable heat. The storage capacity of the stoves is utilized by permitting the gas input to stoves to vary with fluctuations of gas production and use, proper combustion being maintained by automatic burner control. If the stoves are equipped with adequate pressure burners which place the combustion chamber of the stove under pressure, it is often possible to burn gas at a maximum rate equal to twice the average rate. In this manner the stoves act as a flywheel, tending to absorb some of the fluctuations in blast furnace gas supply.

The storage capacity of the blast furnace stove permits of reduction in firing in the event of a temporary gas deficiency. This can be made up subsequently by increased firing. It is possible to reduce the blast temperature and the consequent sustained requirement of gas for firing the stoves, but such action should be anticipated by about fourteen hours to permit compensation by charging additional coke to the blast furnace, the time element being that required for such coke to descend to the tuyere zone in the furnace.

Blast furnace stoves have always been fired by blast furnace gas exclusively. No auxiliary fuel is provided. Because of special conditions existing in certain plants which desire to release blast furnace gas for use elsewhere, projects have been made for burning oil and natural gas at the stoves.

OPEN HEARTHS

The open hearth department is usually the largest consumer of process heat in a steel plant. At the same time it requires the highest temperatures. It is a batch process involving melting and refining operations. The total time of a heat will range from 8 to 16 hours. During the melting period the heat input may be increased substantially above the average rate; during refining operations only enough heat may be applied to maintain temperatures, restricting the input to as low as 15 per cent of the average rate. Figure 1 shows how the fuel input and the heat release in an open hearth furnace vary through the heat.

Coke oven gas has been successfully applied to open hearth furnaces. The gas burns with a transparent flame which is lacking in radiating power. Consequently greater dependence must be placed on heat transfer by convection. Gas velocity, gas distribution and turbulence play a role.

To avoid difficulties associated with transparent flame, it is customary to burn tar or oil in combination with coke oven gas. The flame is directed close to the surface of the bath where its local luminosity expedites heat transfer to the nearby bath more effectively than to the more remote furnace roof. A combination is satisfactory in which 10 to 25 per cent of the heat input is in the tar or oil, the balance being in the coke oven gas. However, in plants where the coke oven gas supply is limited, more of the heat input may be in liquid form.

Mixed coke oven and blast furnace gas is being successfully and increasingly applied to open hearth furnaces. This mixture burns with a rather transparent, bluish flame. In at least one instance in the United States, the gas mixture is being preheated to a temperature high enough to cause some cracking of hydrocarbons, a luminous flame resulting. The mixture tends to a lower theoretical flame temperature than straight coke oven gas, and consequent lower furnace temperature. Absence of potential excessive heat head encourages even heat distribution and minimizes local overheating of refractories. Some variation in the composition of the mixture is permissible.

The fuel requirements of a single open hearth furnace vary. There may be as many as fifteen furnaces in one

shop, and some plants have several shops. In such plants the effect of diversity is to cause a substantially uniform fuel demand. Open hearths commonly operate continuously throughout the week.

Reliability of fuel supply is considered essential, although no serious damage will result if the fuel supply should fail for an hour or so. Most furnaces burning mixed gas are equipped to burn oil or tar in the event of failure or inadequacy of gas supply. Hence the open hearth may be considered as a large and steady consumer for which mixed blast furnace and coke oven gas is well suited. It is somewhat adaptable and accommodating in the event of variation or interruption of gas supply.

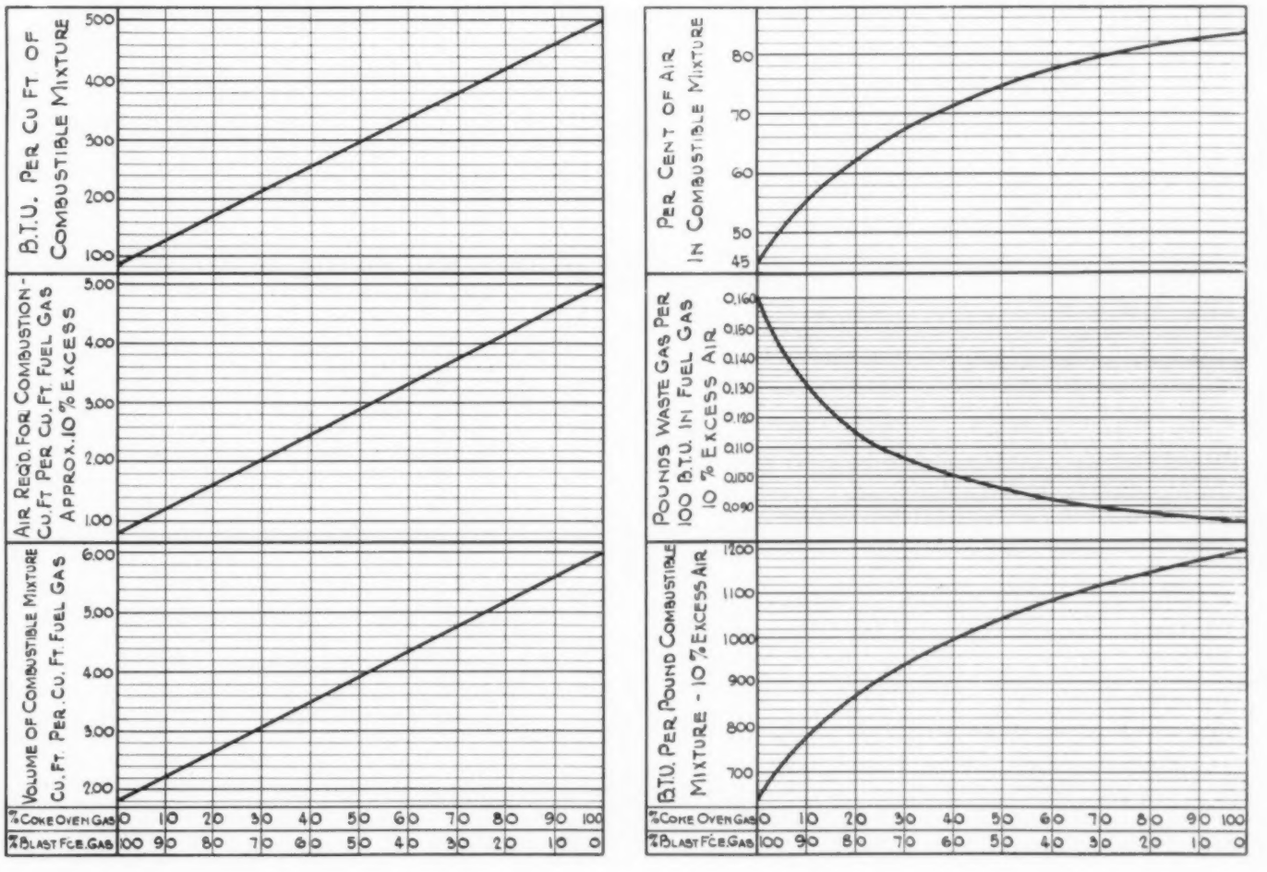
SOAKING PITS AND HEATING FURNACES

Soaking pits and heating furnaces differ strikingly from open hearths in thermal requirements, in that they involve a lower range of temperature, such as 2200 to 2500 degrees F. as contrasted with the 2900 to 3250 degrees F. range required in the open hearth.

In soaking pits and heating furnaces the function is to elevate the steel to rolling temperature, evenly distributed throughout the mass. The question of heat penetration rate arises. A somewhat higher rate of heat penetration may be permissible during the earlier stages of heating, a limited rate of penetration during the later stage being desirable to obtain uniformity of temperature. The rate of penetration to cold steel is limited by possible damage to the steel resulting from wide temperature differences between surface and interior. The permissible heating rate is influenced by the quality of steel being heated.

Soaking pits and heating furnaces may be fired with coke oven gas, mixed gas, or straight blast furnace gas. The use of the latter two fuels is relatively recent. Coke oven gas has long been applied. It is clean and convenient, but tends to be harsh if combustion air is pre-heated. Blast furnace gas gives excellent results at soaking pits where a moderate heat input is required for slow heating with most of the heat transfer by convection. Straight blast furnace gas has been used in continuous heating furnaces, but the cost of such furnaces is rather high. Separately heated regenerators, for preheating the combustion air to a high temperature, are necessary. Mixed blast furnace and coke oven gas makes an excellent fuel for reheating furnaces. The mild, distributed heating obtained with mixed gas is particularly advantageous in furnaces heating thin sections. As compared with producer gas, the cleanliness of mixed gas renders it more adaptable to use with automatic combustion controls. A mixture of about

FIGURE 2—Curve illustrating the possibility of varying calorific value of the fuel to suit furnace conditions during an open hearth heat.


B.T.U. Per Cu Ft of Combustible Mixture
Air Reqd. for Combustion - Cu Ft per Cu. Ft. Fuel Gas Approx. 10% Excess
Volume of Combustible Mixture Cu. Ft. per Cu. Ft. Fuel Gas
% Coke Oven Gas 0 10 20 30 40 50 60 70 80 90 100
% Blast Fce. Gas 100 90 80 70 60 50 40 30 20 10 0
Per Cent of Air in Combustible Mixture
Pounds Waste Gas per 100 B.T.U. in Fuel Gas 10% Excess Air
B.T.U. per Pound Combustible Mixture - 10% Excess Air

33 per cent coke oven gas and 67 per cent blast furnace gas, having a heat value of about 230 Btu. per cu. ft., or any richer mixture, can be employed. It is not usual practice to vary the mixture at individual furnaces, but the mixture supplied to a common mill line feeding a group of heating furnaces may be changed without undue inconvenience. This possibility permits some flexibility in adjusting the supply of the two component gases to the demand.

Individual soaking pits and heating furnaces are relatively small consumers so that variations in their demands are readily absorbed by diversity in any extensive installation. Since most mills discontinue operations during the week-ends, the fuel requirements of these furnaces are reduced to nearly zero over a period of about twenty hours each Sunday.

ANNEALING AND HEAT TREATING FURNACES

Annealing, normalizing and heat treating operations ordinarily involve temperatures on the order of 1200 to 1700 degrees F. Slow, uniform heating is desirable. Preheat of combustion air is not ordinarily practiced. For such duty, blast furnace gas or a lean mixture of coke oven and blast furnace gases, having inherently moderate flame temperature characteristics, are ideal. The fact that such furnaces are generally small consumers and are often rather remotely located, may cause the cost of distribution of blast furnace gas to them to be prohibitive. On the other hand, annealing furnaces of the radiant tube type require the use of straight coke oven gas or a rich mixed gas.

BOILERS

It has long been customary to burn a major portion of the blast furnace gas under boilers. This practice has been due in part to the usual proximity of the boiler plant, the ease and low cost of application, and the readiness with which supplementary fuels can be provided at boilers. It is common practice to burn blast furnace gas in combination with powdered coal or fuel oil, or to provide for the exclusive burning of one of these supplementary fuels in the event of a deficiency of blast furnace gas. When burned in combination, the supplementary fuel feed may be governed automatically as required to meet steam demands and blast furnace gas availability.

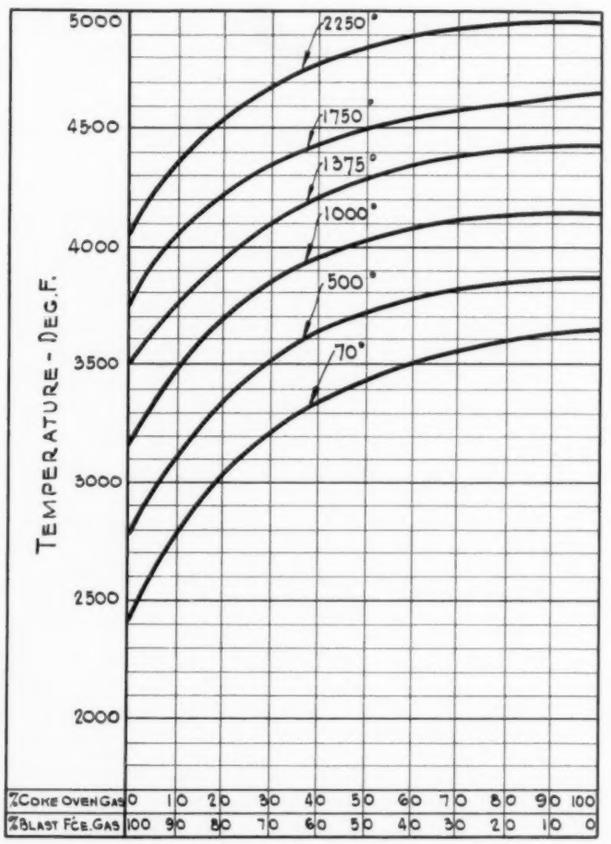
Blast furnace gas is an eminently satisfactory fuel for boilers if these are adapted to its use. Because of the low flame temperature and consequently low furnace temperature, it is desirable that the combustion air be preheated. This is particularly essential when blast furnace gas is used in a steam generator with water walls. Because of the relatively large volume of products of combustion (1.4 times coal), ample furnace volume and adequate provision for convection heat transfer are necessary. When burning cold blast furnace gas, care must be exercised not to reduce the rate of firing so low as to permit the furnace to cool below ignition temperature.

Blast furnace gas may be fired to boilers as received from the dust catcher at a temperature of about 300 degrees F., with the moisture content in superheated condition, and carrying about 3 grains of dust per cu. ft. (standard), or it may be fired in cold saturated condition after wet cleaning. The hot, dirty gas may produce about 5 per cent more steam, a factor of considerable import. The avoidance of gas cleaning costs is an additional saving. The amount of dust carried into the furnace by hot, dirty blast furnace gas, is comparable with the ash in pulverized coal. This dust in the gas may have a salutary influence on combustion in that the hot, dry dust particles glow and assist ignition. On the other hand, hot gas may require a larger gas main, which may be brick-lined to retain the sensible heat in the gas. More or less trouble may be experienced in keeping such a main clean, particularly if the amount of gas transported and the consequent gas velocity vary over a wide range.

In a few instances blast furnace gas is cleaned in electrical precipitators of dry type, retaining most or all of its sensible heat. A cleanliness such as 0.25 gr. dust per cu. ft. is attained. Such gas is well suited for boilers and blast furnace stoves having large checkers.

If washed gas is fired under boilers, it is preferable that it have a cleanliness such as 0.15 gr. dust per cu. ft.

FIGURE 3—Curves giving combustion characteristics of varying mixtures of coke oven gas and blast furnace gas.



or less, and it is particularly desirable that it carry a minimum of entrained moisture. Wet, dirty gas, carrying perhaps 0.3 grains of dust and considerable entrained moisture, can be utilized, but much trouble is experienced at burners and in the gas lines due to sludge, and boiler tubes become encrusted. Moreover, the cold, wet dust tends to extinguish the gas and interferes with ignition at low ratings. Furthermore, entrained water is an immediate and drastic debit against the net heat value of the gas since it must be evaporated and superheated, with the absorption of almost 1/5 Btu. per grain of water.

A choice between hot, dirty gas and cool, washed gas for boilers must depend on local conditions. If only a minor variable fraction of the gas is to be burned under boilers, it is most feasible to utilize the gas in the condition of its preparation for other uses. If, however, a major portion of the gas is to be burned under boilers regularly, the economies and advantages of hot gas should receive some consideration.

Coke oven gas is seldom fired under boilers as it has been considered too valuable for other uses. It may prove desirable to burn some coke oven gas under boilers on week-ends. If coke oven gas is substituted for blast furnace gas at a boiler arranged for burning the latter, provision may be necessary to prevent overcooling of the lesser volume of combustion products in the air preheater or economizer, as pitting may result, particularly in view of the large amount of water vapor in the combustion products of coke oven gas.

GAS ENGINES

Formerly a substantial portion of the blast furnace gas was sent to gas engines driving blast furnace blowers or electric generators. With improved practice in steam plants, the large space requirements, the heavy investment and maintenance charges associated with gas engines, are difficult to justify. The inflexibility of this use and the inability to substitute other fuels are serious disadvantages. Gas engines must be spared by steam-driven units. The advantages which accrue to the burning of the last variable increment of blast furnace gas under boilers, supplemented by other fuel, do not accrue to gas engine operations; in fact, gas engines are a consumer demanding first consideration in the matter of regularity, reliability, cleanliness and uniformity of supply.

FUEL MIXTURES

As previously mentioned, coke oven gas is frequently used in combination with tar or oil at open hearth furnaces. Coke oven gas has been added successfully to hot producer gas. There would appear to be a limited demand for such a combination, except as a means for disposing of an excess of coke oven gas. Coke oven gas has also been used in combination with still gas and the mixture has been used in combination with oil.

It has been proposed to burn blast furnace gas in combination with oil. As yet this practice has not been exploited, but such a combination would seem to have merit.

This discussion deals primarily with the use of the by-product gaseous fuels, coke oven gas and blast furnace gas. The following discussion of mixed gases is therefore directed primarily to the use of these two fuels in combination.

PRINCIPLES OF MIXED GAS APPLICATION

In the selection and application of fuels for steel plant furnaces, it is desirable that two important considerations be met in order that the applications may be most effective and also most efficient. First, it is desirable that furnace temperature conditions be developed which are well suited to the process to be performed. Second, it is desirable that fuel consumption be minimized through the reduction of stack losses.

The second-named consideration commonly requires that the heat in stack gases be used to preheat the combustion air, or both the air and fuel gas. The combustion products leave an open hearth furnace at about 2700 degrees F.; they may leave a soaking pit or a side-door heating furnace at 2000 degrees F.; they often leave continuous heating furnaces at temperatures up to 1000 degrees F. For fuel economy, it is important that a substantial part of the heat contained in the products of combustion at these temperatures be recovered.

If part of the heat in the products of combustion is utilized to preheat the combustion air or the fuel gas, or both, the effect of such preheat is to raise the temperature developed in the furnace by the fuel being used. An amount of preheat which may be desirable from a fuel-economy standpoint may not result in the most advantageous furnace temperatures and consequent heating performance.

The availability of two gaseous by-product fuels of widely differing characteristics offers opportunity, in the steel plant, to adapt the fuel to the needs of the application through the selection of one fuel or the other, or through use of mixtures of the gases in most advantageous proportions. The advantages which accrue through the use of mixed gas are being increasingly recognized.

The curves in Figure 3 show pertinent data concerning mixtures of blast furnace and coke oven gas and their combustion characteristics. The volume of combustible mixture per 100 Btu. in the fuel, for blast furnace gas, is about 1.66 times that corresponding to coke oven gas. The weight of waste gases, per 100 Btu. in the fuel, is 1.9 times greater for blast furnace gas than for coke oven gas. Because of the greater volume and weight of the products of combustion, recovery of waste heat from these products is somewhat more significant as related to the leaner gas mixtures, particularly those containing less than about 30 per cent coke oven gas.

The amount of fuel and heat which can be handled by a given furnace is limited by speed of combustion, gas velocity and draft considerations, on the one hand, and by ability to deliver heat to the charge, on the other hand. The lesser volume and weight of combustion products per 100 Btu. in the fuel contributes to

greater permissible heat release in a given furnace with coke oven gas than with blast furnace gas. The shorter coke oven oven gas flame is another favorable factor. Furthermore, the higher effective flame temperature characteristic of the richer fuel increases the temperature difference or gradient between flame and charge, thereby favoring both radiant and convection heat transfer. The richer fuels enjoy a distinct advantage with respect to rapid heating of cold steel.

It should be noted, in this connection, that preheat contributes to greater total heat release in a given furnace without encroaching on the limitations incident to heat release resulting from combustion. Figure 1 gives an indication of the contribution to heat release made by preheat.

The greater relative volume of combustion products is advantageous to the leaner fuels, particularly with respect to moderate heat release when the temperature of the charge is high and the fuel feed is restricted. The larger relative volume of products may fill the furnace volume better, thus improving heat distribution; it may aid convection heat transfer, thus minimizing the temperature difference necessary between the charge and the flame. The longer flame also favors uniformity of temperature through the furnace. The leaner fuels enjoy a distinct advantage as to quality of heating.

The curves shown in Figure 4 show the influence of gas mixture and preheat on flame temperature. The lowermost curve shows theoretical flame temperatures corresponding to various mixtures of blast furnace and coke oven gas when burned cold in combination with cold combustion air. The next higher curve shows the effect of preheating the air or gas or both to such extent that the combustible mixture has a temperature of 500 degrees F. Other curves show the effect of higher amounts of preheat.

It is impossible to attain the theoretical temperatures shown in these curves. The nearest approach to them can occur in an empty furnace or one in which the charge is fully heated. Under such conditions, all the heat released in the furnace is required to compensate for furnace losses and to maintain the furnace temperature. The maximum actual mean furnace temperature approximates 85 per cent of theoretical flame temperature, depending partly on furnace design, exposure for radiation and insulation.

When a cold charge is introduced into a furnace, it absorbs part of the heat released, thereby restricting the portion of the heat which is available for maintaining furnace temperature. The result is the drawing down of the mean furnace temperature, perhaps to about 50 per cent of theoretical flame temperature.

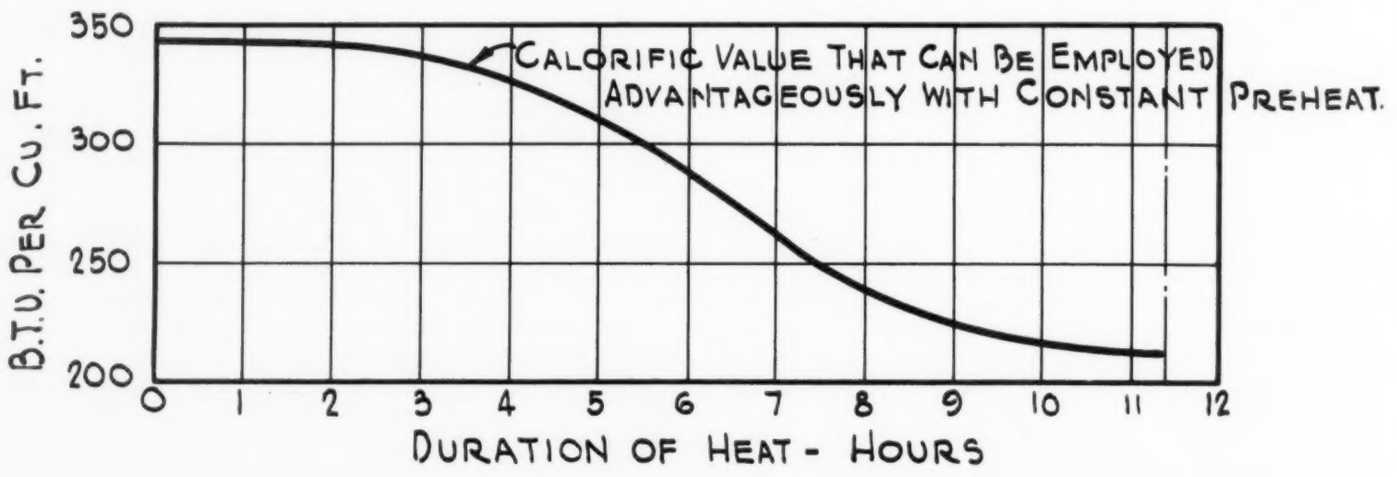
As the charge becomes heated, the gradient between the furnace temperature and the charge tends to decrease. The charge therefore absorbs a smaller portion of the heat release. The furnace temperature increases. An increasing portion of the heat release per unit of fuel is then available and is required to maintain the higher heat level. The furnace temperature attained at any moment is determined by the portion of the heat release which is available to elevate the furnace temperature. If heating were continued indefinitely, the condition would eventually be attained under which the charge would absorb no further heat and "empty furnace" conditions would apply.

Under typical working conditions, a portion of the heat release is absorbed by the charge and the mean furnace temperature approximates 75 per cent of theoretical flame temperature.

Through application of these approximate ratios or percentages to the theoretical flame temperatures shown in Figure 4, the following deductions can be made. These are merely explanatory of established practices.

1. An increase in preheat results in an increase in furnace temperature which accelerates the rate

FIGURE 4—Curves showing theoretical flame temperatures of mixed gas with various degrees of gas and air preheat (10 per cent excess air).



of heating. An increase of 750 degrees F. in preheat may elevate the furnace temperature such an amount as 200 degrees F.

2. The richer fuels enable favorable heating rates (indicated by the disparity between theoretical flame temperature and mean furnace temperature) to be maintained at higher furnace temperatures.
3. A cold charge will draw down furnace temperatures further with a lean fuel than with a rich fuel. Consequently heating is more rapid with the richer fuel. If a very lean gas is used with low preheat, furnace temperatures may be drawn down by a cold charge and cool furnace so low as to jeopardize ignition of the gas.
4. The use of a richer fuel permits the attainment of a given furnace temperature, with a given proportion of the heat release available for the charge, at a lesser preheat.
5. A temperature of about 3250 degrees F. cannot be attained, even with "empty furnace" conditions, through use of a mixture containing less than 30 per cent coke oven gas with 1000 degrees F. preheat. If 1750 degrees F. preheat is employed, a fair rate of heating may be attained. With this amount of preheat, a furnace temperature of 3250 degrees F. could hardly be attained with straight blast furnace gas and all the heat input would be required merely to attain such a heat level.
6. With the richer fuels, unless the charge does absorb a substantial portion of the heat input, furnace temperatures will rise far beyond limits which the refractories can stand. This demonstrates the need of careful adjustment of fuel quantity to restrict furnace temperatures when rich fuels are combined with high preheat. If there is lack of uniformity of heat distribution or of absorption by the charge, use of a rich fuel with high preheat may easily lead to dangerous flame and furnace temperatures in localized areas. If less preheat is employed, the danger of excessive local temperature is reduced.
7. A rich gas mixture in combination with high preheat may be used to advantage to bring the charge up to melting temperature, but if a lean mixture is employed near the end of the heat, when it is desired to deliver little heat to the charge, the danger of attaining damaging furnace temperatures through failure to restrict the fuel feed quickly enough, or through uneven distribution and local heating, is minimized. The manner in which this practice is applied is indicated in Figure 2. This figure may well be viewed in relation to Figure 1. In actual practice, the Btu. content of the gas mixture is adjusted in steps, as the heat progresses, rather than along a smooth curve as shown in Figure 2.
8. If mixed gas containing about 80 per cent coke oven gas by volume (420 Btu. per cu. ft.) be used, it is possible to attain a furnace temperature of 3250 degrees with a good rate of heat input into the charge if the combustible mixture is preheated to 1750 degrees F. Such a mixture might be used advantageously during the initial stages of the heat. Since about 80 per cent of this mixture is air, preheat of the air only to about 2150 degrees F. given an equivalent result. If this amount of air preheat is applied during the later stages of a heat to a gas containing 20 per cent coke oven gas (170 Btu. per cu. ft.), the combustible mixture will have a temperature of about 1300 degrees F., a condition approximately midway between the 1000 degrees and 1750 degree curves. With such a mixture, a furnace temperature level of 3000 to 3250 degrees F. could be maintained only provided there is little or no heat input into the charge. Thus a mixture containing about 20 per cent coke oven gas is a minimum which can be used to hold temperature in an open hearth where only the air is preheated to a maximum feasible temperature of about 2150 degrees F.
9. As applied to heating furnaces requiring a heat level of about 2500 degrees F., blast furnace gas must be given high preheat if a fast rate of heating is to be carried up to rolling temperatures. A heating furnace using blast furnace gas fuel with 1000 degrees F. preheat of the combustible mixture, might be sluggish as rolling temperatures are approached.
10. If rich gas mixtures are used with high preheat, the furnace charge may be heated at high rates up to and well beyond desired rolling temperatures. Hence such combinations tend to be rash, causing uneven heating or washing of the steel. For heating furnaces which will employ high preheat, the use of lean fuel mixtures is indicated. Where but little preheat is to be employed, richer mixtures become desirable. If no preheat is to be employed, only the richest fuels will be adequate.

It should be recognized that the curves indicate general conditions applying when the gases are burned with about 10 per cent excess air at the furnace. Variations from this condition affect the picture. An increase in excess air not only increases the weight of waste gases, but it lowers the flame temperature substantially. The curves do not take into consideration the effect of chemical reactions on open hearth furnace temperatures. In general the curves represent conditions which are attainable with favorable design, construction and practice.

PREHEAT AND RECOVERY OF STACK LOSSES

From preceding discussion it should be evident that the amount of preheat which may be most advantageous from the viewpoint of furnace operation, is not a fixed quantity. When a charge of cool steel is being heated or melted, a high degree of preheat could be utilized without danger of attaining excessive furnace temperatures. On the other hand, when little heat is being delivered to the charge, a limited amount of preheat would be desirable, particularly with rich fuels, in order

to limit the theoretical flame temperature and the consequent furnace temperature.

No practical method has been developed for varying preheat. It is prevailing practice to provide fixed preheat facilities, resulting in fairly uniform preheat. For a given fuel, it is desirable that the amount of preheat be such that a moderate rate of heat delivery to the charge can take place when the charge approaches or attains its maximum desired temperature.

As a general indication of relations between furnace temperatures, preheat and recovery of heat in the products of combustion, the following examples are cited:

1. With fuel mixtures containing more than 60 per cent coke oven gas, advantageous furnace conditions in a 2500 degrees F. furnace are obtained with no preheat and consequently no waste heat recovery. With straight blast furnace gas burned at a furnace equipped with regenerators or recuperators, a recovery of about 55 per cent of the sensible heat in the combustion products between 2000 degrees F. and 800 degrees F. is indicated to be adequate to the attainment of good furnace temperatures.

While it is true that heating furnaces burning coke oven gas are often equipped with regenerators or recuperators, such provision is primarily directed at the recovery of waste heat. Some increase in theoretical flame temperature inevitably results, with consequent tendency to furnace temperatures higher than necessary. Preheat tends to shorten the flame and is thus inimical to heat distribution resulting from slower combustion.

2. In an open hearth using straight coke oven gas, advantageous furnace conditions are obtained with a heat recovery of about 80 per cent of the heat in the waste gases contained in a 2700-1400 degrees F. range, or about 45 per cent of a 2700-400 degrees F. range. With a mixture containing about 25 per cent coke oven gas (200 Btu. per cu. ft.) a heat recovery of about 80 per cent of a 2700-800 degrees F. range is necessary from a furnace operating standpoint. This would be a full practical recovery for this range in view of inevitable heat losses in the regenerators due to radiation and possible infiltration.

In general, the leaner mixtures afford greater possibilities for complete waste heat recovery without attendant furnace conditions of a character which require close regulation of fuel input and uniform distribution of combustion and heat absorption in order to avoid excessive furnace temperatures. This statement does not apply to cases where the waste heat recovered is not returned to the furnace, i. e., to the cases where waste heat boilers are used.

Improved types of recuperators which are now available, are a factor favorable to the more extensive application of lean gas mixtures for heating furnace duty.

QUANTITATIVE RELATIONSHIPS

The selection and mode of application of by-product fuels in the steel plant is naturally influenced by the availability of those fuels. Individual plants differ widely, dependent primarily upon the relative coke, pig iron and steel making capacities, the kind of coal, ore and iron; whether all steel is by the open hearth process, the amount of scrap used, the extent of rolling operations, etc. Existing pipe lines, furnaces, regenerators, and other equipment influence the practice adopted in by-product gas utilization. It may be enlightening, however, to consider the relations of gas supply and possible demand, for a rather typical new plant where such restrictions were non-existent. Table I is taken from a project for the Dnieprostal Steel Works in the Ukraine, U.S.S.R. The initial plant as projected, included four blast furnaces with coke ovens adequate to supply these furnaces. Most of the steel melting capacity employed the open hearth process, although some electric furnaces were included. A more or less typical complement of mills was involved. Electric power was to be received from the Dnieprostroy hydroelectric development nearby. Steam turboblowers were installed to serve the blast furnaces.

The first column in Table I shows that all process heat requirements exceed by a small margin the heat available in the form of coke oven and blast furnace gas. However, if the steam for blast furnace and coke oven uses is excluded, the demand for fuels for heating and melting operations is about 92 per cent of the supply. Hence, if all gas were devoted to heating processes, there would remain 8 per cent for firing under boilers.

The second column shows that blast furnace gas alone is sufficient to supply about 60 per cent of the demand, divided as indicated. The third column shows that the process fuel demand is about three times the coke oven gas supply. The fourth and fifth columns show the percentage subdivision of process heat requirements, inclusive and exclusive of process steam for coke ovens and blast furnace blower.

While 64 per cent of the heat content of the by-product fuels at this plant is in the blast furnace gas, this represents 91 per cent of the gas volume. Nine per cent of the volume is coke oven gas containing 36 per cent of the total heat. If the two gases were mixed in toto, a lean mixture would result, having a heating value of about 125 Btu. per cu. ft. Such a fuel would not be well adapted for use at the open hearths and heating furnaces, for which a richer fuel is desirable. Moreover, if all the gas were mixed at one point it would not be possible to select for each consumer the kind of gas or the mixture best suited to its requirements. Nor would it be possible to vary the mixture at the open hearth with the progress of the heat. It is more rational to distribute the gases separately and to use portions of the blast furnace gas without mixing, thereby obtaining a richer mixture for the balance.

It is entirely logical to allocate straight blast furnace gas for use at coke ovens and stoves. This gas is well adapted to these operations. The layout of the plant in question is favorable to easy distribution of blast furnace gas to these consumers. Moreover, these consumers require gas seven days a week and therefore introduce no week-end storage problem.

After thus allocating 55 per cent of the blast furnace gas to stoves and coke ovens, the remaining 45 per cent might be mixed with the coke oven gas. The resulting mixture would contain about 82 per cent blast furnace gas and 18 per cent coke oven gas, the heat value being about 165 Btu. per cu. ft. This is still too lean for open hearth and heating furnace use.

An additional 12.7 per cent of the blast furnace gas may be used very advantageously at the soaking pits. If about 15 per cent of the blast furnace gas be allocated to annealing furnaces and to boilers to produce steam for coke ovens and blast furnace use, a total of about 84 per cent of the blast furnace gas will have been allocated. The remaining 16 per cent, mixed with all the coke oven gas, gives a mixture of about 63 per cent blast furnace gas and 37 per cent coke oven gas, with a heat content of about 240 Btu. per cu. ft. Such a gas can be employed at open hearths and heating furnaces if provision is made therefore.

The above figures show in a general way, by illustration, how the by-product fuels available in a plant can be allocated to process consuming units. The relations shown in the table apply to capacity operations. If the plant as a whole, or any departments thereof, modify their production rates, the relations change. It is of course necessary to provide for any combination of conditions which may arise. If auxiliary fuels must be provided for, investments are involved which must be included in the economic picture.

ECONOMIC FACTORS

It has been indicated that there are several definite potential consumers of blast furnace and coke oven gas in steel plants. Some practical considerations influencing the allocation of these gases have been mentioned. It is further of consequence that these gases are used where they will realize the greatest money savings. Stated in another manner, it may be said that the gases should be sold to the consumers which can pay the most for them. Table II. has been prepared to give some conception of the merit of various applications and to indicate the factors involved.

The figures in this table are based on the following assumptions, which are merely approximate or typical:

Steam coal cost.....$3.50 per ton delivered
Gas coal cost.....$4.00 per ton delivered
Fuel oil cost.....3½ cents per gal.
Electric power cost...8 mills per kwh.
Fixed charges.....15 per cent

The cost of transportation is based on 1200 ft. of gas pipe line between the respective gas sources and the consuming departments. The picture is not greatly changed if the length of lines is doubled.

In the case of oil, the cost of fuel plus necessary storage, heating and pumping, plus maintenance and fixed charges on storage and handling equipment, brings the cost to about $0.247 per million Btu. In a plant which must fire oil or tar, the value of the tar is substantially the same as that of oil, unless tar can be sold at a premium.

The cost of producer gas is indicated to be substantially lower, per million Btu., than oil. The cost figures for mixed gas are based on a mixture having 230 Btu. per cu. ft. The charges include only the costs of preparation and delivery of the coke and blast furnace gas components. In the case of a mixture of coke oven gas and oil, the fuel cost of the oil only and all handling costs for both fuels, are included. Fixed charges on all fuel preparation and transportation requirements are included.

In comparing these fuels for use at an open hearth

TABLE I.

Process Heat Requirements in a Steel Plant in Relation to By-Product Gas Supply.

Department	Heat Required				
	Per cent of total heat in combined coke oven and blast fce. gases	Per cent of heat in blast fce. gas	Per cent of heat in coke oven gas	Per cent of all process heat, incl. steam	Per cent of process heat excl. of steam for blowers and coke ovens
Coke ovens (ovens)	17.4	27.2	48.5	16.2	19.0
Process steam	5.1	7.9	14.1	4.7	....
Blast furnace (stoves and losses)	18.1	28.2	50.5	16.8	19.6
Turbo blowers	10.5	16.0	28.5	9.8	....
Open hearth	28.1	43.8	78.5	26.1	30.5
Soaking pits	6.2	12.7	22.6	7.6	8.9
Heating furnaces	13.8	21.5	38.3	12.8	15.0
Annealing and miscellaneous furnaces	6.4	10.0	17.9	6.0	7.0
	107.6	167.3	298.9	100.0	100.0
Deficit	7.6	67.3	198.9		

cognizance must be taken of the difference in fuel input required. The use of producer gas introduces the substantial losses in producers. Mixed gas shows the highest economy for reasons already indicated. Fuel consumption figures will vary in individual cases. The relations shown in Table II. are typical. These figures show that, under the conditions assumed, oil fuel costs $1.19 per ton ingots. If half the oil is replaced by coke oven gas, the fuel cost per ton ingots is $0.63. The fuel value of the coke oven gas for this application is the difference, i.e., $0.56 per ton ingots. The requirement of coke oven gas is 2.4 million Btu. per ton ingots. The value of the gas is $\frac{\$1.19 - 0.63}{2.4} = \$0.234$ per million Btu.

Similarly, if coke oven gas and oil were used in lieu of producer gas, the value of the coke oven gas would be $\frac{\$1.18 - 0.63}{2.4} = \$0.229$ per million Btu. This figure may be discounted if the producers already exist, so that their fixed charges continue whether or not the replacement fuel is used.

If mixed blast furnace and coke oven gas is used in lieu of oil, the value of the mixed gas is $\frac{\$1.19 - 0.068}{4.5} = \$0.25$ per million Btu.

If mixed blast furnace and coke oven gas is used in lieu of producer gas, the value of the mixed gas is $\frac{\$1.18 - \$0.068}{4.5} = 0.247$ per million Btu.

At the heating furnaces similar conditions exist. If

TABLE II.

Evaluation of By-Product Gases.

Elements of Fuel Cost: Typical costs per million Btu. in the fuel:	Oil or Tar	Coal for Producer Gas	Coke Oven Gas and Oil 50% Mix	Mixed Gas Coke Oven and Blast Furnace 230 Btu. per cu. ft.
Fuel cost	$0.240	$0.148	$0.1200	.....
Preparation	0.002	0.04	0.0017	$0.0016
Transport	0.002	.....	0.0043	0.007
Maintenance	0.0015	0.005	0.0017	0.001
Fixed charges	0.002	0.015	0.0038	0.0055
Total Cost	$0.2475	$0.208 (coal)	$0.1315	$0.0151
Gas Evaluation:				
At Open Hearth:				
Millions of Btu. per ton ingots	4.8	5.7 (coal)	4.8	4.5
Fuel cost per ton ingots	$1.19	$1.18	$0.63	$0.068
Bid price for coke oven gas in gas-oil mixture:				
Per ton ingots	0.56	0.55		
Per million Btu.	0.234	0.229		
Bid price for mixed gas:				
Per ton ingots	1.122	1.112		
Per million Btu.	0.25	0.248		
At Continuous Heating Furnaces:				
Millions of Btu. per ton heated	1.4	2.0		1.2
Fuel cost per ton heated	$0.346	$0.416		$0.018
Bid price for mixed gas:				
Per ton heated	0.328	0.398		
Per million Btu.	0.273	0.332		
At Soaking Pits:				
Millions of Btu. per ton ingots	1.2	1.6		1.0
Fuel cost per ton ingots	$0.298	$0.333		$0.015
Bid price for mixed gas:				
Per ton ingots	$0.283	$0.318		
Per million Btu.	0.283	0.318		

mixed gas is used, somewhat lower fuel consumption may be expected. The figures tabulated show that if mixed gas is used in lieu of oil, the value of such gas is about $0.275 per million Btu. If used in lieu of producer gas, the value of the mixed gas is about $0.332 per million Btu.

Similarly at the soaking pits, it is indicated that mixed blast furnace and coke oven gas has a value of about $0.283 to $0.318 per million Btu. under the conditions assumed. Since such a mixture can be replaced by straight blast furnace gas with equivalent performance, blast furnace gas has a value on this order for this application.

The values of mixed gas determined above refer to the component of coke oven gas at the ovens before boosting the pressure for transmission, and the component of blast furnace gas at the blast furnace plant prior to cleaning and boosting.

These figures indicate that, under the conditions assumed for this illustration, heating furnaces and soaking pits can bid a higher price for mixed gas than can open hearths. This result is in conformity with general experience but local considerations may affect the picture substantially. The cost of supplying mixed gas to scattered mill furnaces is likely to be higher than the cost of delivery to a bulk consumer such as the open hearth. Heating furnaces with regenerators or recuperators suitable for mixed gas may also involve additional first cost.

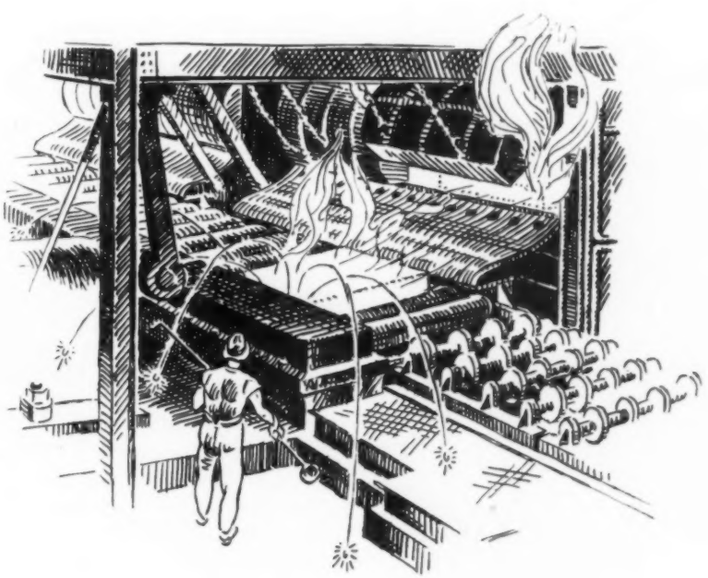
These figures for valuation of mixed gases for open hearth and heating furnace use are not inclusive of savings in refractory costs which may occur through use of milder fuels. Nor do they include such important factors as improved quality of steel resulting from better heating, decreased scale loss or elimination of the necessity for removal of sulphur from coke oven gas, which may be possible if it is diluted with blast furnace gas. Other local or intangible factors may have a bearing.

Blast furnace gas burned under boilers replaces coal which costs about $0.16 per million Btu., including preparation costs. If the gas is burned in cold, saturated condition, the boiler efficiency is about 4 points lower with the gas than with coal. The gas thus has a replacement value of about $0.152. From this must be deduced $0.015 for preparation and transport, giving a net comparative value of the untreated gas of about $0.14. If the gas is burned hot, a substantial increase in heat value results from retention of the sensible heat and cleaning costs are avoided. On this basis the gas has a value of about $0.15 per million Btu.

If blast furnace gas replaces coke oven gas for underfiring coke ovens, it attains a value equal to that of coke oven gas, less the rather nominal cost of preparing and transporting the blast furnace gas for this use.

It has been rather customary to evaluate coke oven gas according to the price which it will bring if sold to a utility. In some cases such an evaluation may not be entirely justified. If producer gas or oil is used in plant processes, the price which such consumers can bid for the gas for replacement purposes is a more realistic measure of value. Furthermore, it should be noted that coke oven gas acquires a substantial increment of excess value if, through mixture with blast furnace gas, it enables the latter to acquire a value such as $0.27 per million Btu. for process use, as compared with $0.15 per million Btu. for boiler use.

The examples given in previous paragraphs bring out the fact that in many plants blast furnaces gas is the major by-product fuel. The problem is to use that lean fuel in processes where it has a higher value than when used under boilers. This can be accomplished if available coke oven gas is directed to enrichment of a mixture rather than to separate application. Rather lean mixtures can be used if preheating is adequate. The use of mixed gas offers advantageous heating performance simultaneously with improved economy.



TODAY and TOMORROW

By B. F. Fairless

Presented at Annual Banquet A. I. & S. E. Convention
. . . . Pittsburgh, Pennsylvania, September 28, 1939

▲ IT is a privilege and a pleasure to meet with the Association of Iron and Steel Engineers here in Pittsburgh. From the personal standpoint I am delighted to find such a pleasant occasion upon which to greet so many friends and acquaintances. A spirit of cordiality is apparent on all sides. Matching it in depth and quality is the evident interest of your members and guests in those numerous serious problems which go to make up their daily tasks. More important still is the cooperative attitude, expressed in your deliberations and proceedings, dedicated to the improvement of engineering services to industry.

B. F. FAIRLESS

Your group comprehends, within its membership, a significant portion of the total talent required for the successful conduct of the iron and steel business. The engineer, or the man with engineering training, has attained a position of indispensability in practically all lines of commercial enterprise, and we know of none in which his role is of more consequence than in the production of steel.

This industry, which engages our mutual interest, is a thing of momentous value to all of the people, for it provides so many of the important requirements of mankind. There is no need to enumerate them here. Rather I wish to emphasize the thought that our first concern is to see that an efficient and progressive steel industry stands ready to meet its obligations, insofar as the efforts of an efficient, progressive personnel can bring about the desired result.

The signs of the times indicate that for an unknown period, you, as engineers of the iron and steel industry, will be called upon to deal with many a difficult problem arising from the present critical situation. By critical situation I mean a pronounced upward surge in the production of steel at a time when powerful factors are making for an extremely unsettled state of affairs in the world abroad. Your professional training and adopted methods insure a reasoned and dispassionate approach to all such matters. The way of the engineer, or the scientist, or the technologist, is like that. He objectively analyzes each case at hand, studies cause and effect, seeks the truth, and applies constructive measures accordingly. It is timely and appropriate that we should discuss here tonight the merits of employing such methods in the solution of other categories or problems. The reasoned and dispassionate approach of the engineer may be exceedingly useful in quarters in which it has been all too much neglected.

During the year 1939 the people of America have heard much about "The World of Tomorrow", the theme of the great World's Fair in New York City. It is a theme which attracts the interest of all of us, for

naturally we expect to live and play some part in that world. Moreover, we would be glad to learn, in advance, as much as possible about the conditions which might surround us and our children, perhaps our grandchildren, in the years to come.

No one, of course, knows precisely what tomorrow will bring forth, so the major portion of our interest hangs upon the bold conceptions, guesses, and imaginings set forth by those who have represented their predictions in visible form. It is hardly likely that in the midst of all the conjecturing and planning which evolved the projected World of Tomorrow, provision was made for any such ghastly situation as now confronts the peoples of the earth. The exhibits of our own country and of the sixty foreign nations participating in the Fair, unanimously accent the arts and products of peace as those which are to shape our future. On that basis a beautiful picture has been created, a worthy thought advanced, and a widely-held hope expressed.

Something, however, has gone amiss. Our World of Today, staggering in its pathway, gives little promise of an early fulfillment of the dreams and hopes of its people. Attention and effort are feverishly devoted to unwelcome pursuits. The World of Tomorrow is confounded.

Only twenty years ago many believed that the world finally had been made safe for democracy,—for civilized man, for all human beings, and that one of the greatest lessons of all time had been learned. Through the ordeal of war, men, women, and children had undergone a full measure of mental and physical suffering, sufficient, the survivors thought, to establish their right to an enduring peace. Prolonged political and economic upheavals, following in the wake of four years of destruction, and reflecting its devastating effects, seemed to lay additional convincing emphasis upon the errors of the courses heretofore pursued. It is little wonder then, that given some measure of recovery, men should plan for a better tomorrow, and conceive and build great exhibits to symbolize their will to work constructively for the future.

The present distressing condition of world affairs is evidence enough that the roadway leading into the future is still beset with some of the same old difficulties that have plagued mankind since the earliest days. All of the knowledge and experience acquired by the human race in centuries of patient endeavor has not been sufficient to forestall the use of destructive violences as a means of attaining certain aims and ambitions, or of shaping the destinies of The World of Tomorrow.

PRACTICAL WISDOM NEEDED

Unfortunately, war is still one of the ready instruments employed in dealing with social and political relations. In periods of sanity it has been denounced and renounced repeatedly by individuals and nations, nevertheless it persists. Perhaps the requisite amount of wisdom has yet to be distilled from the attained knowledge and experience of mankind to dictate or compel a more temperate and rational course in the solution of international problems. Wisdom is the word for emphasis. Practical wisdom is undoubtedly the greatest need on all sides, for certainly after these thousands of years, there is no dearth of knowledge and experience. Men know the better ways of dealing with each other, but lack the sagacious insight to adopt and follow them consistently.

History tells us that during the Middle Ages more than sixty per cent of the time was spent in fighting. The trend happily has been downward, for during the most recent century the percentage has fallen to approximately twenty five. But what has been gained in the lesser amount of time devoted to conflict has been offset by the multiplied intensity of war and its attendant suffering. The great conflict of twenty-five years ago destroyed more than ten million lives, whereas prior to 1914 all of the wars since the French Revolution killed less than half that number. With regard to the increasingly effective engines of war available for use today, some one has said, in warning, "if mankind does not end war, war will end mankind". That, of course, is an extreme view, but it comes too near to possible truth to be reassuring.

No one has been able to compute accurately the economic cost of the World War, for its expenses are still being incurred. Expressed in terms of a familiar currency, the estimated three hundred and forty billions of dollars is probably conservative, taking little account of stand-by charges and contingent liabilities. In the light of subsequent events, and in the face of the present world situation, the important question is, what did the nations purchase at so great a price? Certainly not their necessary supply of wisdom. Moreover if the lessons of 1914 to 1919 teach anything, they teach the futility of attempting to arrive at world-wide gain, contentment, and economic progress through world-wide conflict. Many of you who are here today learned those lessons not from books; to you they were a harrowing personal experience. And "Flanders Field" and "Journey's End" are still remembered in America. It remains to be seen how much of real wisdom has accrued to the people of these United States within the past twenty-five years.

Were it possible to quarantine war, as has been suggested, or to isolate oneself completely from a troubled world, there might be reason for less concern over international strife abroad. A hundred years ago the chances of aloofness were better than they are today. Many factors now render such perfect isolation difficult. The ready availability of means for rapid communication and transport, the established custom of international trade, the reliance upon foreign sources for essential materials, all operate against the possibility of effective detachment from external matters. Moreover, an aloofness, based upon indifference, is hardly compatible with the natural sympathy for fellow men in the throes of mortal combat.

We know at once that a substantial derangement of political, economic, or social order anywhere on the earth has an immediate effect upon our own affairs. Therefore we are rightly concerned with what is now transpiring, even though that concern relates first and foremost to the maintenance of a state of neutrality. We are solicitous about what may happen, and on guard to avoid involuntary entanglement in hostilities.

The spectacle which lies before us in foreign lands is indeed a distressing one. It shows that in this twentieth century, although men have learned to deal in an enlightened manner with nature, they have failed, as yet, to deal wisely enough with human nature. You, and I, and all of us, as professional and business men, are appalled at the possibilities inherent in the present struggle. Our minds normally do not encompass the thought of spreading death and desolation for the purpose of accomplishing our ends. The rational and dispassionate method adopted by the engineer in approaching his problems stands in sharp contrast with the one repeatedly used in the attempted solution of international disputes. Let us examine the two more closely. On the one hand there is an analysis of cause and effect, a study of the relation of part to part, a search for facts, and a building with due regard for natural laws. On the other there is a foundation of passion, jealousy, and fear, a resort to pressure politics, and a widespread destruction of life and property. Which of these methods, do you think, partakes of the essence of wisdom?

It is a sad commentary upon the ways of human nature that the so-called enlightened peoples of the earth have not applied the most constructive methods to all aspects of living. They have certainly employed superior techniques in developing the more material pursuits, and have made significant progress thereby. The teachings of science, engineering, and technology have been used to remake, several times over, the methods of industry. Within the comparatively short period of a hundred years the advancement has been amazing—so outstanding in fact that we are said to be living in the "industrial age". This application of the scientific method to the production of goods has not only brought about astounding improvements in all lines of industry, but has exerted a profound influence upon the social order by raising the standard of living.

One need not go back a full hundred years to catalogue an impressive list of benefits accruing from the course pursued by industry. It has consistently taken into its workshops the great inventions and discoveries, the advances in engineering, and the findings of its research workers, and has made the resultant devices and materials available to the people at large. The telephone, telegraph and radio the modern steam engine turbine, electric generator and motor, the typewriter, the internal combustion engine, agricultural machinery in profusion, and the airplane are cited as illustrative. Millions of mechanical aids and implements of production are assisting men and women in the performance of their daily work. Generated power, in abundance, is available practically everywhere. The installed horsepower in the United States today, if divided equally among all of the inhabitants, has been estimated to be equivalent to the services of approximately one hundred servants.

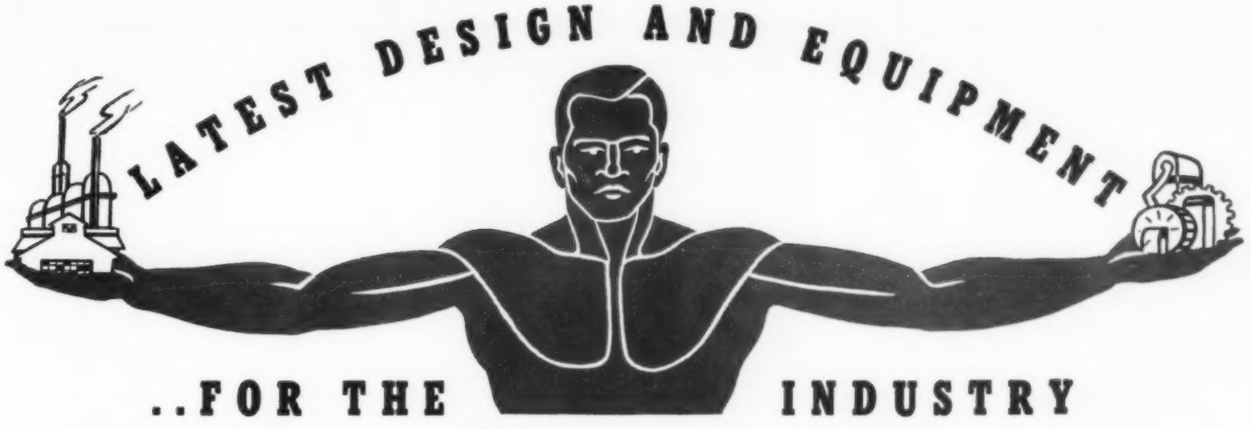
In a large measure the long work day of the nineteenth and earlier centuries has gone from industry. Real wages have increased. Much of the drudgery of work has been shifted from human shoulders to machines. The lightening of burdens has reached into millions of households as well as into factories, mines, and fields. Natural resources are more efficiently used and effectively conserved by the application of scientific methods. Thousands of useful products unknown to our forefathers now make life's walks progressively easier.

You gentlemen of the Association of Iron and Steel Engineers, from your intimate contact with the steel industry, know of the remarkable progress it has made in much less than a century. Enormous forward strides have been taken in the improvement of processes, equipment and products. Year by year, the methods of science and engineering have come more and more into play, without the sacrifice of any real values established by experience. Today the steel industry is equipped to serve, as never before, the needs of the people.

This brief word-picture of progress in industry has been drawn in the interest of supporting what was said a little while ago in deprecation of war. The constructive results of one stand out in comparison with the stultifying effects of the other. Now, we ask, of what use is all this progress and improvement in one sector of life, if it can be readily offset and nulified by the use of unwise methods in another? Why develop the implements and conditions for better living if men cannot learn to live together?

As a strong suggestion, we add the question which is probably now in your minds—might it not be possible to apply more of the scientific or engineering approach to the solution of political and international problems, in the hopes of securing more of its characteristic results? It is unreasonable to suppose that only with respect to matters lying outside the field of international relations can men ascertain facts, apply exact knowledge, reason from cause to effect, correct errors, and act constructively. A system which works, one which has proved its effectiveness and worth over a long period of years, certainly deserves serious consideration in every quarter. Let us all make an effort to have more of its principles injected into the handling of political matters, national and international Already the day is late, but men will be living on the earth for many years to come. We are interested in contributing something of lasting value to the World of Tomorrow. The various nations will not be more isolated then than now. Therefore we must have a will to mend injustice promptly and rationally, and learn to live together. The protection of our inalienable rights—life, liberty, and the pursuit of happiness depends upon our ability to gather and apply wisdom.

The engineers, along with others who use or approve the objective and dispassionate procedure, would do well to make their voices heard as citizens, calling upon political leadership everywhere to partake of their methods in the solution of international problems.



REPUBLIC OPERATES FIRST OF TWO NEW TUBE MILLS IN YOUNGSTOWN DISTRICT

▲ Republic Steel Corporation has completed and placed in operation a new tube mill at the Youngstown, Ohio, plant. This new tube mill is designed to make one-half inch to extra heavy three inch butt welded pipe in any lengths from one foot to forty-five feet by the Fretz-Moon process. The first of its kind to be installed in the Youngstown district, it will be followed immediately with a second unit.

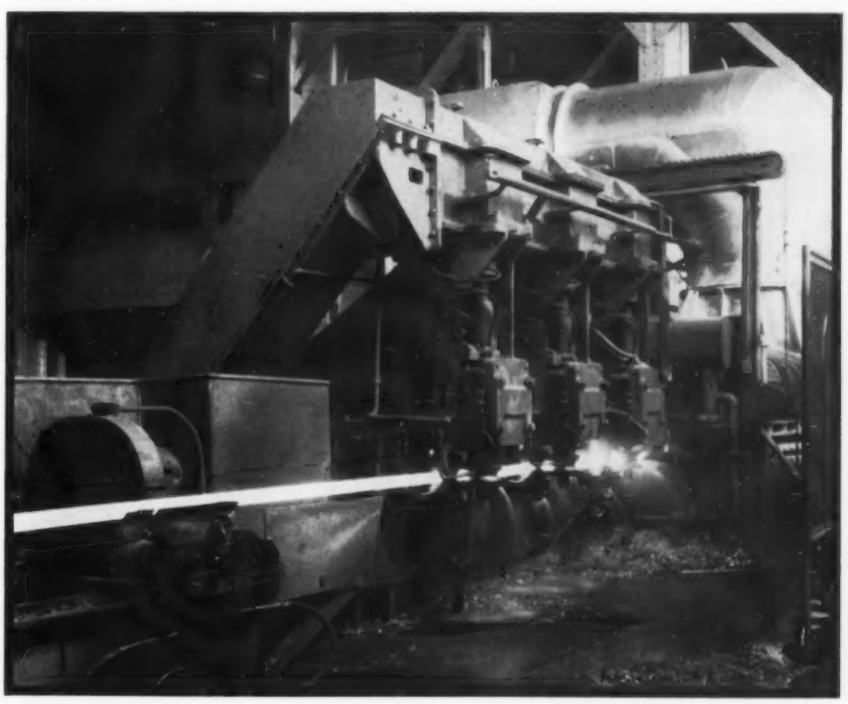
When the second unit is completed the two mills will use a continuous butt weld process in which the skelp is formed in a forming mill rather than being drawn through a bell die, as is the usual practice for making butt weld tubing. Because of the improvement in design of furnaces, both as to efficiency and control, the tube made by this new process is of better quality as to size, weld, and inside cleanliness.

In the manufacturing of tubes by this process, the skelp is brought to the mill in coils varying in length from 300 to 1200 feet. The skelp is uncoiled, passed through a roller leveler, and the end of each new coil electrically welded to the trailing end of the preceding coil. This makes one continuous strip to be charged into the furnace.

From the welder, the skelp is run out through pinch rolls onto a floor storage table. This looping table allows the uncoiling of the skelp to be interrupted long enough to be welded without interfering with, or slowing down, the front end being charged into the furnace. As a further precaution against undue tension or buckling being introduced into the hot skelp as it passes through the furnace, it is sent through a second, carefully controlled loop just before being charged. A dancer roll rheostat, introduced in the looped skelp, maintains the size of this loop by speeding up or slowing down the motor driving a second set of loop inch rolls.

A recuperator type furnace, 150 feet long, is used, with three heating zones which are fired with rows of burners using coke oven gas. The first zone is used as a pre-heating chamber, to bring the temperature of the skelp up gradually. In the second and third zones temperatures in the neighborhood of 2500 degrees F. prepare the skelp for forming. The recuperators with which the furnace is supplied are used not only for fuel economy but to obtain the rapid combustion needed.

The skelp is carried through the furnace on tubular, water-cooled skids which minimize the accumulation of scale. A blast of air, directed at the edge of the skelp as it leaves the furnace, serves to remove any dirt remaining on the metal and adds oxygen under pressure which serves



The tube leaves the rolls at speeds from 87 to 400 fpm. A traveling hot saw cuts the tube to required lengths.

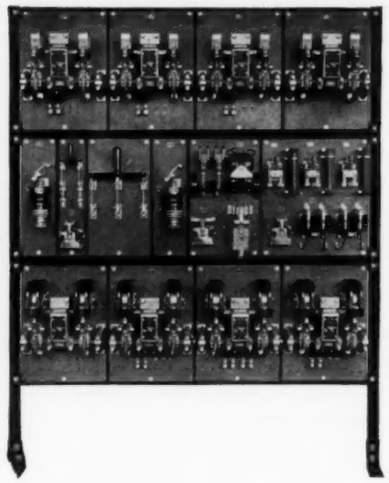
to whip up the temperature of the edges of the skelp several hundred degrees. Forming and welding of the tube immediately follows the exit of the skelp from the furnace. Three sets of grooved rolls, each set consisting of one pair of vertical and one pair of horizontal rolls, handle these operations. The first set is the forming roll. The second and third sets guide the welding process which is promoted entirely by the heat in the skelp itself.

The skelp leaves the rolls at anywhere from 87 to 400 feet per minute, depending on the diameter of pipe being produced. A traveling hot saw, actuated by flag switches, cuts the tube to required lengths, with an accuracy of plus or minus ¼ inch. After being cut to length, the tubes are carried away from the saw by a conveyor, moved slowly across a transfer cooling rack, and delivered to a second conveyor which carries the pipe to a descaler. Here, in addition to removing the outside scale caused by oxidation, a certain amount of straightening and sizing is performed. A third conveyor, on the exit side of the descaler, carries the tubes to a second cooling rack, from which they are removed and sent through the usual finishing processes.

NEW CRANE CONTROL SAVES POWER COSTS

▲ For use on electrically-operated cranes and hoists a new alternating current dynamic braking hoist control has been developed by the Electric Controller and Manufacturing Company. This new control eliminates the mechanical load brake on the crane and is operated entirely from the alternating current source of power. It may be used with any standard a-c. wound rotor hoist motor. No conversion units are required and no additional collector bars are needed, thus making installation easy on existing as well as on new cranes. When installing this new control on existing cranes, it is only necessary to disconnect the pawl, band or similar locking device which causes the mechanical load brake to operate in the lowering direction, thus permitting the motor and gearing to be free-running in both directions.

There are three major advantages of this new magnetic hoist controller:



This new crane control eliminates the mechanical load brake on the crane and is operated entirely from the a-c. source of power.

power saving; elimination of upkeep cost of mechanical load brake; and faster lowering speeds. At the same time, the control has the ability to permit very short, accurate inching movements of any load within the crane's capacity. Power saving is an important item, because instead of absorbing the energy of an overhauling load in the mechanical load-brake and using power to drive the load down on all points of the controller, this new control allows a heavy, overhauling load to drive the motor as a generator on all points except creeping speed points, thus returning power to the line.

Hyper-synchronous speeds are obtained on the last two points of the master switch and allow the motor to run at speeds above synchronous speed, as much as fifty per cent above synchronous speed of the motor. These speeds are obtained only with overhauling loads and can be secured on any crane where this feature of higher speed is desired. These increased speeds are particularly well suited on magnet cranes, in which the lowering of an empty magnet may be speeded up on its return for another load.

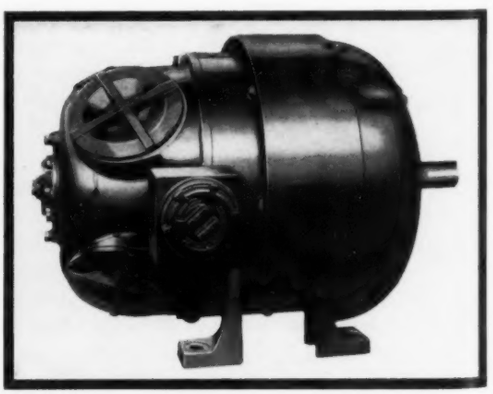
NEW D-C. MOTORS INCREASE SAFETY

▲ The Reliance Electric and Engineering Company is now prepared to build explosion-proof direct current motors as large as 75 hp. Recent changes and improvements over the original design now make it possible to provide a complete range of sizes from 1 hp. up to 75 hp., all of them tested and approved by the Underwriters' Laboratories, Inc., for Class 1, Group D hazardous locations.

The motors are designed to operate safely in places made dangerous by the presence of gases and vapors such as are produced by methane, acetone, benzene, the various alcohols, common pyroxylin solvents, and the vapors of various petroleum distillates, including gasoline.

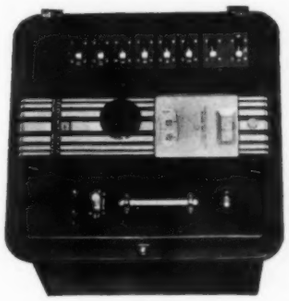
Basic requirement for motors to operate safely in such locations is that if gas or dust inside the motor enclosure should become ignited, the resulting flame is prevented from escaping to the outside air. At the same time the motor enclosure must have ample strength to withstand, without bursting or loosening of joints, the highest internal pressure which might develop in the event of an explosion of gases such as those present about the motor. Finally, the construction of the motor must be such that in the event of a burnout, the motor enclosure will not reach a temperature sufficient to cause surrounding vapors to ignite.

A complete range of sizes from 1 to 75 hp. is available in these new explosion-proof d-c. motors.



MULTIPLE SWITCH FOR POTENTIOMETER

▲ Ample space for toggle-type switches, for connecting any one of a number of couples to the measuring circuit, is provided in a new temperature indicator made by the Leeds and Northrup Company. Installed wherever convenient, it enables an operator to measure temperatures of near or distant couples with equal reliability, by simply turning a knob, until a pointer comes to zero, and reading a temperature scale.



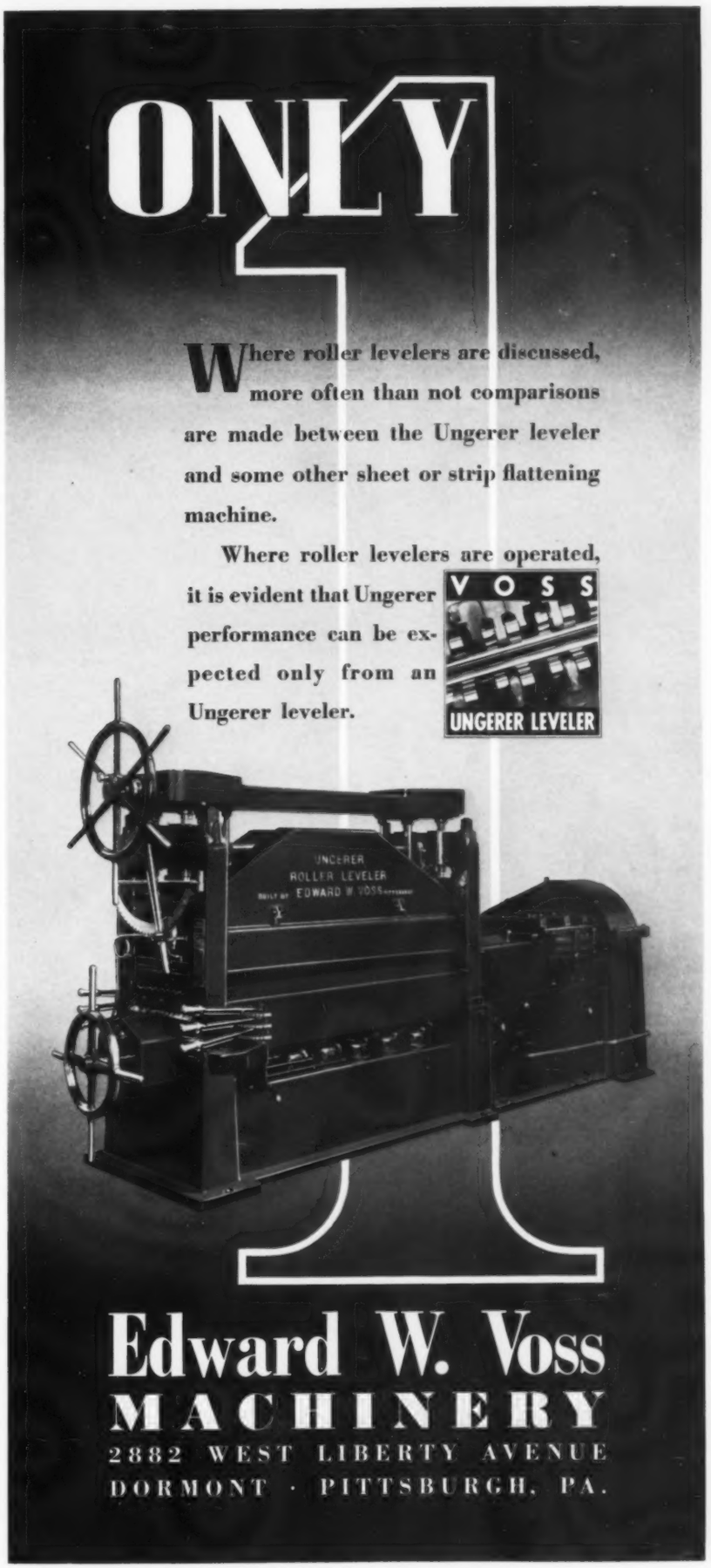
Use of a potentiometer measuring circuit—hand-standardized, but with automatic reference-junction compensation—eliminates uncertainties due to circuit-resistance variables. Scale is practically uniform and equally accurate throughout, and can be calibrated for single or double range, the latter for use with similar or different couples. Built-in terminals, check key and mercury thermometer can be included for checking with a portable indicator.

The rigid metal case mounts flush in panel, but can be equipped with hangers for surface mounting. The galvanometer is a sturdy replaceable unit. The only maintenance is occasional dry cell replacement. Warning that dry cell must be renewed is given when a red disc appears above the indicator scale.

MODERN RESEARCH DEVELOPS NEW OIL

▲ For many years technicians have searched for a satisfactory substitute for China wood oil, or tung oil, which is imported from China. This oil is used in the manufacture of insulating varnishes by the John C. Dolph Company.

In view of the conditions which


ONLY
Where roller levelers are discussed, more often than not comparisons are made between the Ungerer leveler and some other sheet or strip flattening machine.
Where roller levelers are operated, it is evident that Ungerer performance can be expected only from an Ungerer leveler.
VOSS
UNGERER LEVELER
UNGERER
ROLLER LEVELER
Edward W. Voss
MACHINERY
2882 WEST LIBERTY AVENUE
DORMONT · PITTSBURGH, PA.

periodically shut off the supply of tung oil from China, considerable experimentation has been conducted in this country in an attempt to grow tung trees. Since 1908, when the first tree was planted near Tallahassee, Florida, much progress has been made and today many groves are producing nut bearing trees, the fruit of which is pressed to produce American tung oil.

Among the many advantages of the American-grown tung oil are greater purity, uniformity and greater freedom from acid. This oil is produced with modern machinery which is in contrast to the crude hand presses used by the Chinese. Investigation has proven that the change of oil does not affect the qualities of "Chinalak" insulating varnish. In fact, the use of this American tung oil guarantees a more uniform product. Consequently, as a result of negotiations with the General Tung Oil Corporation, the Dolph company has arranged to use American tung oil exclusively in the manufacture of their insulating varnish.

ARC WELDER USES IMPROVED DESIGN

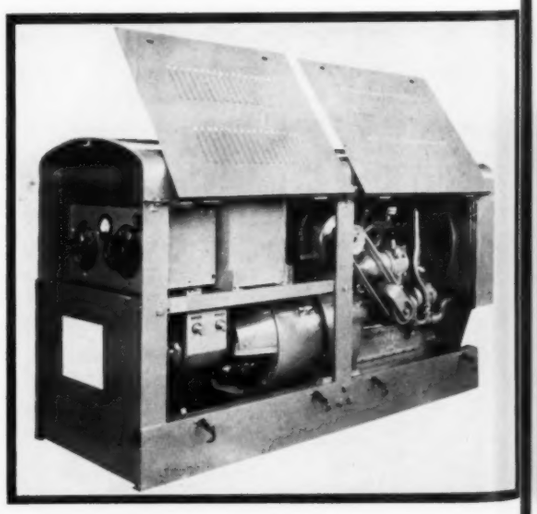
▲ A new 300 ampere diesel engine driven arc welder, which is equipped with gasoline engine starting rather than the conventional motor starter with storage batteries, a decisive advance in diesel design, has been announced by the Lincoln Electric Company.

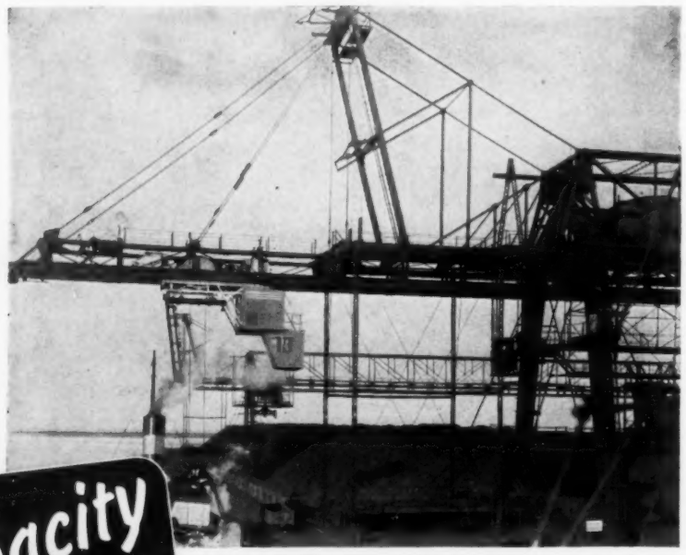
This new welder simplifies the use of diesel power which was first made available to users of engine driven arc welders. The diesel engine which drives the welder compares favorably with gasoline engines in dependability of starting, simplicity, weight and cost, as well as in operating speed.

The gasoline engine used for starting the welder is a small auxiliary mounted above the diesel engine. It is started by means of a hand crank. A belt drive, engaged by means of a clutch, connects the starting engine to the diesel. Starting in extremely cold weather is facilitated by the fact that the cooling system of the small gasoline starting engine is connected into the cooling system of the diesel. This arrangement makes it possible to warm up the diesel by running the starting engine a short time and allowing the heated water to circulate through the diesel engine.

The new diesel driven welder is said to cut fuel costs 33 to 86 per cent, depending upon the type of fuel oil used. The diesel uses only 1.5 gallons

This diesel engine driven arc welder is equipped with a gasoline engine starter, which is a small auxiliary mounted above the diesel engine.





Capacity Doubled by DRAVO

Does the work formerly requiring two bridges

● The Pittsburgh Coal Company operated two 6-ton coal bridges at their Superior, Wis., docks. One bridge alone was incapable of handling the total traffic, yet the operating costs of the two bridges constituted too great an overhead. Dravo designed a man trolley of aluminum, greatly increased the speed of travel without over-stressing the structure, and raised the capacity of one bridge to 12 tons. By eliminating the use of the second bridge, operating costs were reduced proportionately.

Whether the problem is one of modernizing old equipment, replacing obsolete handling machines or designing special facilities to meet new problems, consultation with Dravo Corporation may prove to be of great value to you. Added to its ability to fabricate and erect, design and put into commission ideas as shown above, Dravo Corporation has had years of experience building docks, retaining walls, plant foundation—everything that enters into the problem of terminal facilities. Bulletin 403 describes mill foundations and terminal equipment. Bulletin 202 describes revolving cranes. Either will be sent on request. Inquiries relative to specific problems may be addressed to

DRAVO CORPORATION
ENGINEERING WORKS DIVISION

SHIPYARDS: PITTSBURGH, PA.—WILMINGTON, DEL.
GENERAL OFFICES AND SHOPS: NEVILLE ISLAND—PITTSBURGH, PA.

of fuel oil per hour at full load operation, as compared with 2.75 gallons of gasoline per hour in the case of the conventional gasoline engine welder drive. Total savings, including such items as transportation of fuel, loss, etc., are, in many cases, as high as 40 cents per hour.

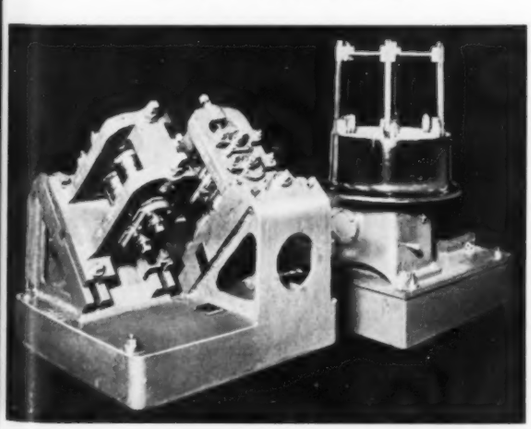
PLANISHING MILL FOR WIRE FINISHING

▲ A new development by the Lewis Foundry and Machine Division of Blaw-Knox Company looks like a pilot mill but is really a production unit of novel type. It is a planishing mill equipped with a coil winder which was developed in response to the request of a wire producer.

It is designed to give lustre to dull coated wire without damage to the coating. Efforts to brighten the wire by drawing through dies inevitably resulted in some loss of coating. This loss is avoided by the rolling action of the two-pass mill.

The two roll stands are at 90 degree angles to each other to insure planishing of the full surface of the wire. Motive power is applied through the winder. The unit is built to keep pace with one wire production line, the wire coming from the coating bath in rough coils, being set on reels, then drawn through the mill and rewound into finished coils. The total weight of the unit shown is about 1600 pounds. Company engineers report that the design can be adapted to provide a sizing mill at the end of a rod mill roll train.

This planishing mill, which resembles a pilot mill, is designed to give lustre to dull coated wire without damage to the coating.

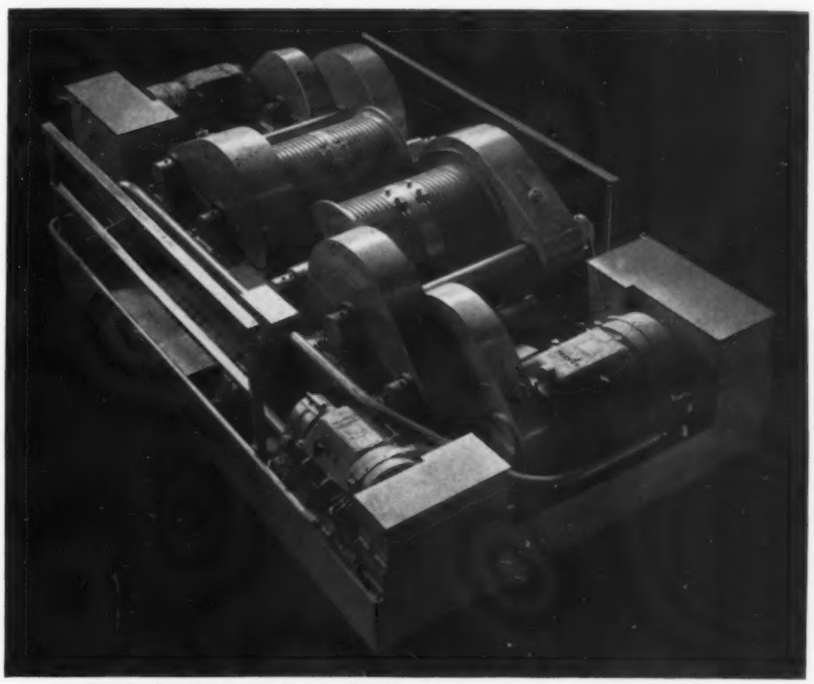


REGULATORS IMPROVE MOTOR OPERATION

▲ General Electric Company has announced new "Diactor" generator-voltage regulators for use with alternating- and direct-current machines. The new regulator will be available in six ratings for generators rated 15,000 kw, 3600 rpm. and smaller machines at correspondingly lower speeds. The smallest of the new regulators is designed for generators up to 25 kw.

The quick-action, wide-range rheostatic-type regulator contains an improved torque element which eliminates all pivots and bearings. A self-aligning spring suspension precludes all maintenance at this point. A great reduction of weight in the torque assembly has cut down the inertia, providing a smoother regulation curve.

This automatic generator voltage regulation provides increased illumination of lights, more satisfactory operation of heating appliances, and assurance that motors operate in accordance with their design characteristics.



Trolley for 10-ton, 80'-0" span Cleveland bucket crane for steel mill service

BUCKET TROLLEYS
***for rigorous* STEEL MILL SERVICE**

Note the clean-cut appearance of this compact all-welded Cleveland bucket trolley.

Built to stand hard service with minimum maintenance. If necessary, parts are easily removed. Hoist machinery shafts supported on side frames. Gear cases oil-tight, yet easy to inspect or remove. Weather-protection covers for brakes.

For smooth operation Cleveland all-welded Cranes can't be beat.

THE CLEVELAND CRANE & ENGINEERING CO.
Wickliffe, Ohio

CLEVELAND CRANES
ALL-WELDED OVERHEAD TRAVELING CRANES
Other products: CLEVELAND TRAMRAIL and STEELWELD MACHINERY

FORK TRUCKS USE NEW LIFT SYSTEM

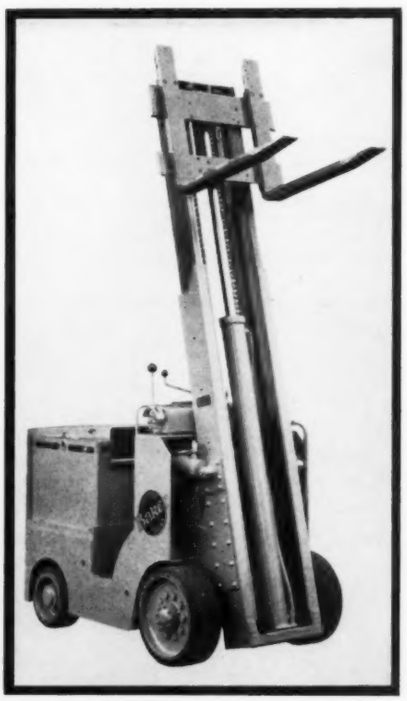
▲ Production of a new series of center-control fork trucks, in capacities from 2,000 pounds to 7,000 pounds, has been announced by the Baker-Raulang Company. These trucks are available in tilting or non-tilting, telescoping or non-telescoping models as required.

The lifting system of these trucks is completely new and embodies recent developments in hydraulic mechanisms. This system comprises a gear pump driven by a standard motor, a release valve, and a jack cylinder. The control is arranged so that putting the control handle into the lifting system opens the valve in the appropriate manner and starts the pump motor. Putting the control into the lowering position opens the valve and permits the fluid from the jack cylinder to return to the reservoir, the speed of lowering being entirely within the control of the operator. The tilting system is essentially the same as the lifting system, being operated by the same motor and pump, but naturally having separate control and valve, and there are two cylinders provided to tilt the uprights. The lifting piston rod is sealed to prevent leakage of oil and any oil which may pass the piston into the upper portion of the cylinder is returned to the reservoir by a bleeder line.

In the telescoping models, the uprights and the jack cylinder are so designed and proportioned that a total fork lift of 126 in. is available with the standard overall height of 88 in., suitable for box car work. A most important feature of this design is that the forks will lift 24½ in. before the inner telescoping uprights start to move, increasing the overall height. This is particularly valuable in box car work or in other locations with limited overhead clearance.

The frames are high-tensile steel plates, arc welded, while the uprights are machined channels of abrasion-

Embodying recent developments in hydraulic mechanisms, the lifting system of these trucks is capable of handling heavy loads with great flexibility.



Scale banished ! Production increased

A SLAB MILL had serious trouble with a dense scale that the high pressure sprays could not knock off. A Hays Supersensitive OT Draft Recorder was installed which revealed a large amount of oxygen being fed into the furnace during the charging period. The pressure was adjusted to plus 5/100 in., water-scale was practically eliminated and production noticeably increased.

Two draft values, two pressure values, two differential values, or a combination of any two of these three values may be recorded. These "OT" Recorders are sensitive enough to register accurately increments of .0025 in. water yet are husky enough to stand up under the jars and dirt of steel mill operation. Write to 955 Eighth Ave., Michigan City, Ind. for Bulletin 37-232.

The HAYS CORPORATION
SINCE 1907 COMBUSTION INSTRUMENTS AND CONTROL MICHIGAN CITY, INDIANA, U.S.A

resisting alloy castings. The rear end of the frame is provided with a heavy iron casting which performs the dual role of bumper and counterweight for the overhanging load.

The power axle is equipped with a single-reduction worm drive with 4-pinion differential and is non-steering. The patented wide-angle steering axle is mounted at the rear of the truck in semi-elliptic springs and is so designed that the steering centers are outside the wheels permitting the tires to roll when negotiating a turn and eliminating "scrubbing" of the tire tread. Steering is accomplished by a wheel. On trucks of 4,000 pounds capacity and over, all wheels are mounted on tapered roller bearings and hydraulic wheel brakes are provided on the drive wheels.

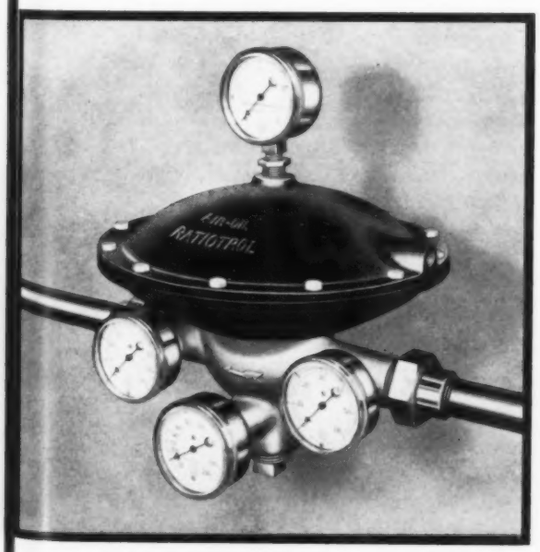
NEW CONTROL GIVES STEADY ATMOSPHERE

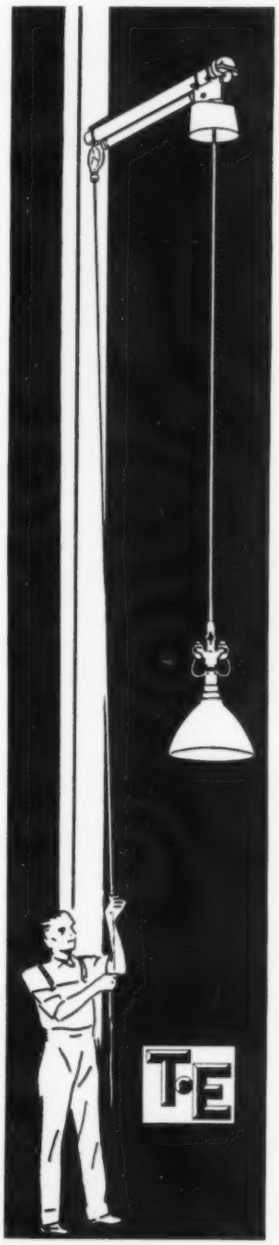
▲ Industrial research has now perfected a definite control over the atmospheric conditions in the heating chamber of the oil-fired furnace. The advantages and possibilities of such control has been widely demonstrated in the gas-fired furnace. This new control is the "Air-Oil Ratiotrol" and has been developed by the North American Manufacturing Company. The control has been tested in the laboratory and under actual plant operating conditions for several months. It has made definite savings in oil consumption and has maintained a constant atmosphere, giving protection to the steel being treated in the furnace.

The simplicity of operation is one of the most interesting features. The control accurately proportions the flow of fuel oil and its combustion air by controlling pressures and making them dependent upon each other. The air pressure alone becomes the dominant factor while the number of burners and their individual settings have no effect on the operation.

The control maintains a constant atmosphere despite fluctuation of oil or air pressure, despite varying rates of fuel input or the manipulation of individual burners.

This control proportions the flow of fuel oil and its combustion air by controlling pressures and making them dependent upon each other.





Portrait of a Man

Speeding Production

In countless operations, Production depends upon the presence of adequate, proper light . . . and such light doesn't come from dirty bulbs or grimy fixtures.

By making fixture-servicing quick and thorough, without interfering with the work of others, Thompson Hangers (lowering . . . disconnecting) speed up Production. And because they also save time and equipment and eliminate accidents, Thompson Hangers save their cost, on the average, in less than two years.

Why not ask a Thompson engineer to show you what this equipment can do for you?

Listed in Sweet's Catalogue File for Mechanical Industries, MacRae's Blue Book, Thomas' Register and Electrical Buyers' Reference. Complete catalogue available on request.

Thompson equipment is sold through leading electrical distributors in the United States and Canada.

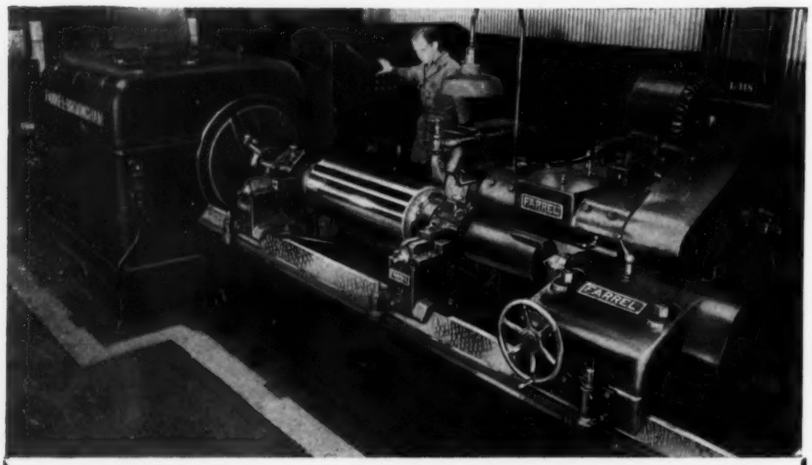
THE THOMPSON ELECTRIC CO.

1101 POWER AVE., N. E. CLEVELAND, OHIO

MAGNET CRANE AIDS MATERIAL HANDLING

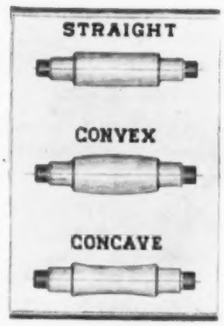
▲ With the steadily increasing demand for scrap metal and pig iron, scrap iron purveyors are adopting new and more efficient handling methods. The Harnischfeger Corporation has developed a magnet crane, known as "Model 255," which has a 39 in. circular magnet, and 40 ft. boom, and a capacity of more than 1½ tons of pig iron castings and similarly high capacity for other types of metal handling service. The crane itself, exclusive of the magnet, has a capacity of 5,200 lb. and 25 ft. operating radius, and as much as 9,800 lb. capacity at a 15 ft. radius. Equipped with a modern magnet cable reel, and an 85 ft. tag line, the crane is driven by a 35 hp. motor-generator set, which works under 220 volts, 3 phase, 50 cycle current. A tail cable bracket prevents the cable from catching on or under the crawler track. The crane has a waterproof cable receptacle, to facilitate working in wet weather.

This crane has three forward speeds, ranging from ⅝ to 2½ miles per hour. It is easily maneuverable. Tractor-type crawlers do away with the annoyances often experienced with old-fashioned crawlers. Built of alloy steels, all-welded the magnet crane attains greater strength and rigidity with less weight.



FARREL ROLL GRINDERS

Assure Maximum Output of Precision-Finished Rolls



The Farrel Automatic Crowning and Concaving Attachment automatically controls roll shape. Straight, convex or concave contours are ground exactly symmetrical on both halves of the roll.

◆

For full information send for copy of Bulletin No. 111.

Continuous operation of a machine means maximum output. The design and construction of the Farrel Heavy Duty Roll Grinder permit continuity of operation . . . . . obviate the necessity for frequent stops to make adjustments and to correct defects attributable to dependence on the operator's skill. Maximum output of rolls ground to close accuracy and with fine finish is thus obtained.

Automatic and semi-automatic features permit close control of roll accuracy and finish to meet predetermined standards. Rolls of any material can be ground with extreme precision and with any finish which can be obtained with wheels now available. Heavy roughing or fine finishing can be done equally well. Straight, convex or concave contours are ground to exact symmetry and accuracy. A perfect surface free from marks of any kind is produced.

When rolls are ground with the accuracy and finish obtained in a Farrel Heavy Duty Roll Grinder rolled metal strip and sheet with better quality surface and more accurate gauge is produced in the mill.

FARREL

FARREL-BIRMINGHAM COMPANY, Inc.
ANSONIA, CONN.
New York • Buffalo • Pittsburgh • Akron • Chicago • Los Angeles

NEW MERCURY LAMPS FOR BLUEPRINTING

▲ A completely new type blue print machine, embodying as a major improvement the use of a new high pressure mercury quartz lamp, will be ready for announcement shortly after January 1, according to officials of the Charles Bruning Company, Inc.

In view of tests showing that this new light source overcomes the disadvantages inherent to carbon arcs, Bruning officials say that the new Hanovia lamp will replace carbon arcs in blue print machines. They point out that the new Hanovia high-pressure mercury quartz lamp should not be confused with the ordinary low pressure mercury tube used for illumination and adapted to small, slow-speed blue printers. The Hanovia Chemical and Manufacturing Company guarantees a lamp life of at least 1,000 hours without any appreciable diminution of light volume during the life of the lamp. Test runs on a model of the new Bruning mercury blue print machine have been made at a speed of 20 feet per minute from new pencil and ink tracings using medium speed blue print paper—a speed not approached by most carbon arc machines.

You can't salvage TOASTED WIRE

You can scrape burnt toast and save it for the breakfast table, but there isn't anything you can do to restore toasted wire to dependable current carrying condition once heat has ruined it.

When wire insulated with vegetable or other organic materials is installed in a hot location it's just like putting bread in a toaster. The insulation eventually becomes so dry and brittle that vibration opens cracks and makes it ready for moisture-produced short circuits, repeated repairs and finally, replacement. Just how long this takes depends only on the intensity of the temperature . . . the hotter the quicker. And if the wire should ever catch fire, the flames will gallop along it, burning off the insulation and igniting everything inflammable in the vicinity.

Think of burnt toast when you're wiring around steam lines, boilers, furnaces and other hot spots and use a wire that won't dry out under high temperatures or burn under any condition. Rockbestos heat-resisting wires are heat-sealed and fireproofed with inorganic asbestos which is also highly resistant to oil, grease and corrosive fumes. They reduce equipment outage and maintenance expense. For advice, recommendations, samples and catalog write to Rockbestos Products Corporation, 939 Nicoll St., New Haven, Conn., or telephone the nearest sales office — see below.

TEN TESTED ROCKBESTOS VALUES

1. Heatproof
2. Fireproof
3. Permanent
4. Lower maintenance cost
5. Resists heat and vibration
6. Saves work
7. Oil and Greaseproof
8. High overload capacity
9. Permanently flexible
10. Greater carrying capacity

New York Buffalo Cleveland Detroit Chicago
Pittsburgh St. Louis Los Angeles San Francisco Portland, Ore. Seattle

ITEMS OF INTEREST

Howard L. Dawson was named engineer in charge of repairs, maintenance, and lubrication for the Carnegie-Illinois Steel Corporation, with headquarters at Pittsburgh. Mr. Dawson was formerly maintenance superintendent at the Edgar Thomson Works of Carnegie-Illinois. He studied metallurgy and machine construction at the Carnegie Institute of Technology. He was first employed as a draftsman at the Edgar Thomson plant in 1912, and later became, in turn, efficiency engineer, construction engineer, master mechanic, and maintenance superintendent.

Frank C. Farrell was appointed district manager of the Buffalo district of Republic Steel Corporation. In 1903, Mr. Farrell got his first job in the steel industry as a water boy, in what is now the Carnegie-Illinois Steel Corporation. Six years later he became turn foreman in the company's Bessemer plant and the following year joined Youngstown Sheet and Tube Company in the same capacity. He remained with Youngstown Sheet and Tube Company until 1928, when he was general superintendent at Youngstown. In 1928, he went to Cleveland to become assistant general manager of Steel and Tubes, Inc. Following the merger of Steel and Tubes with Republic Steel Corporation, Mr. Farrell was transferred to Warren where he had charge of the steel division. In May, 1937, he was made assistant district manager at Warren and in November, 1937 he became assistant district manager of the central district, holding this position until his present appointment.

George W. Putnam was appointed assistant district manager of the central alloy district of the Republic Steel Corporation, Canton, Ohio, succeeding Frank C. Farrell. Mr. Putnam went to Republic in 1933 from the American Rolling Mill Company's Butler plant, where he was superintendent of the open hearth department. From 1919 to 1921 he served as a rim designer for Goodyear Tire and Rubber Company. After a short term as a state highway engineer he joined the American Rolling Mill Company at Middletown, Ohio.

J. H. Graft, formerly superintendent of the electrical department of the Youngstown district of the Republic Steel Corporation, became assistant district manager of the Warren district. J. M. Ashley, Mr. Graft's assistant at Youngstown, succeeds him as superintendent of the electrical department. Mr. Graft was born in Connellsville, Pennsylvania, where he graduated from high school. He was employed for three years at the West Penn Power Company, and for the next three years at the Standard Mines of the H. C. Frick Coke Company. Following this he spent sixteen years at Youngstown Sheet and Tube Company's Campbell Works, and for seven years as electrical superintendent. Early in 1936 he joined the Republic Steel Corporation as superintendent of the electrical department of the Youngstown district.

Frank R. Burnette has been appointed construction superintendent for the Carnegie-Illinois Steel Corporation, with headquarters at Pittsburgh. Mr. Burnette formerly was assistant chief engineer of the American Steel and Wire Company, Cleveland. His experience has ranged from laborer through supervisory and executive positions in operations and engineering with several subsidiary companies of the United States Steel Corporation. He was employed at the Farrell Works of Carnegie Steel Company in 1905 and three years later entered Ohio Northern University, where he was graduated with a degree in civil engineering in 1910. After graduation he was construction inspector at the Gary, Indiana, Works. He joined the American Steel and Wire Company in 1916, and successively became assistant coke works superintendent, superintendent of construction and assistant chief engineer.

Ralph K. Clifford was recently elected as vice-president in charge of operations for all the plants of the Continental Steel Corporation, Kokomo, Indiana. Mr. Clifford, who since 1937 has been works manager of the Kokomo division, has been identified with the Continental organization for 32 years. He began his career in the steel industry in 1907 with the Kokomo Steel and Wire Company working during school vacation periods. For two years after his graduation from the University of Michigan in 1914 he taught in Michigan high schools, later becoming chief chemist, chief metallurgist, and chief inspector at the Kokomo plant of Continental. He was appointed assistant general superintendent in 1923, and two years later general superintendent. He became works manager in 1937.

L. M. Kirk has been made superintendent of the No. 2 open hearth at the Gary Works of the Carnegie-Illinois Steel Corporation. Mr. Kirk went to the Gary Works as superintendent of mould preparation in January of this year from the Worth Steel Company, Claymont, Delaware, where he had been assistant open hearth superintendent since 1936. Prior to that time he was employed for five years by the Bethlehem Steel Company at Johnstown, as assistant master mechanic, general foreman of open hearth gas house, general foreman of stock yard, and general foreman open hearth pit and mould preparation building.

George McMorran becomes assistant superintendent of the No. 2 open hearth of Carnegie-Illinois Steel Corporation's Gary Works. Mr. McMorran was first employed at Gary Works in 1937 as general foreman of the No. 2 open hearth after 25 years of service with the National Tube Company, American Steel and Wire Company, Illinois Steel Company and Youngstown Sheet and Tube Company. He was made assistant superintendent of the No. 4 open hearth in May of this year and remained in this capacity until his present appointment.

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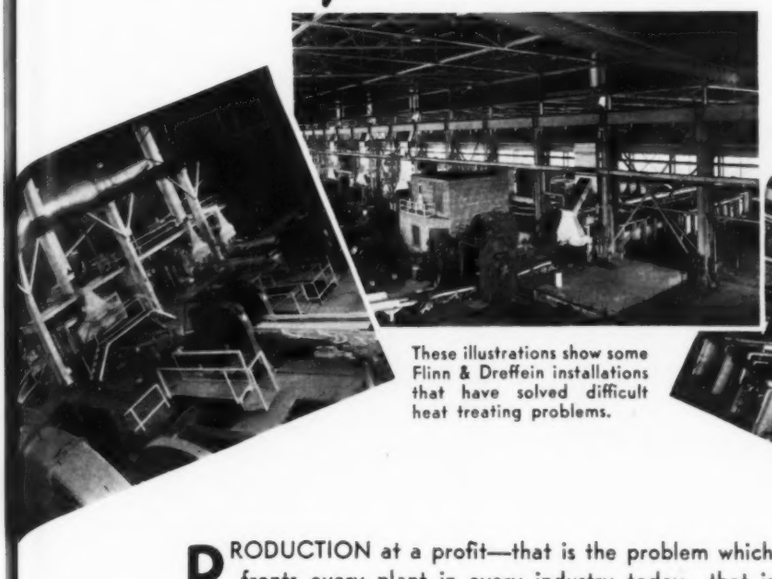

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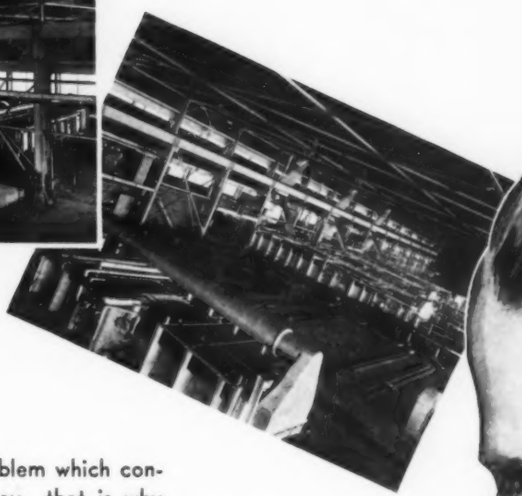

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